Impacts of carbon pricing on the hunting, fishing and trapping economy in the Inuvialuit Settlement Region

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Non-technical summary

A main feature of the 2019 Pan-Canadian Framework on Clean Growth and Climate Change is the reduction of greenhouse gas emissions through government taxation of those emissions, often referred to as a "carbon tax." The Government of the Northwest Territories is currently implementing a carbon pricing program in compliance with this federal policy.

The Inuvialuit Settlement Region is distinct from southern and more urban areas of Canada by virtue of its remote location and its vibrant traditional economy, based on hunting and fishing, that produces tremendous economic and social value. The traditional economy supports Inuvialuit food security and nutrition, builds trust and social capital, and promotes both physical and mental health. However, because of its non-monetary nature, the traditional economy is largely invisible to national- and territorial-level economic statistics. Avoiding a disproportionate burden on Indigenous peoples is a core principle of the Pan-Canadian Framework, but the impact of carbon pricing on traditional economies has not yet been accounted for in the implementation of carbon pricing, in the Northwest Territories or elsewhere.

Based on the Inuvialuit Harvest Study (IHS), at least 122,677 kilograms of food were harvested in the ISR in 2018. The retail cost of comparable market food substitutes for this food is over 3.18 million dollars. These estimates correspond to approximately 44.1 kg or $1,150 per Inuvialuit beneficiary living in ISR communities. Comparable retail foods (pork, beef, poultry, fish) in this quantity would produce between 1,082–1,171 tonnes CO_2-equivalent emissions per year if shipped by food mail. Importantly, these estimates are based only on harvests reported in the IHS, and as such should be considered minimum estimates. The total amount of food, replacement cost, and carbon emissions incurred through replacements are likely much more, possibly as high as double our estimates.

The Inuvialuit Traditional Economy is highly dependent on imported fossil fuels, both for the importation of necessary supplies and for powering hunting vehicles including snowmobiles, boats, and all-terrain vehicles. This dependence is not recent and is the result of complex historical factors. Further, in the Arctic these modes of transportation cannot be easily replaced with greener technology at the present time. We estimate that 165,985 litres of gasoline, worth approximately $292,133, would have been used in the production of harvests reported in the 2018 IHS. We estimate the carbon impact of this volume of gasoline to be 395 to 502 tonnes CO_2-equivalent emissions per year.

The other major source of carbon emissions associated with the traditional economy is production of vehicles. Unfortunately there is limited data available to calculate the quantities and frequencies of vehicle purchases in the region. Nevertheless, our calculations suggest that, even if the entire carbon emissions of vehicle production were applied to food production (and not to other benefits of the traditional activities such as recreation and health), the traditional economy could still produce a net carbon savings relative to imported market foods. More data would be required to provide a clearer estimate of the total carbon inputs to the traditional economy.

Fossil fuels and vehicles used in the traditional economy will be heavily impacted by carbon pricing; but no exception has been made for fuels used for subsistence purposes in the Inuvialuit Region. However, Inuit hunters throughout Canada are already experiencing difficulty affording the gasoline and equipment required for traditional harvesting activities. Further increases in the cost of harvesting will reduce the ability of many Inuvialuit to engage in harvesting, which may lead to poorer nutrition, poorer health, and a lower quality of life in Inuvialuit settlements.

Based on these findings, we recommend that mechanisms should be put in place to protect the Inuvialuit Traditional Economy from potential negative effects of carbon pricing. Such mechanisms need to account for the fact that harvest production is unevenly distributed across households and that a substantial portion of harvested foods are redistributed within and between Inuvialuit communities through sharing. We note several limitations to our study as the result of a lack of available data on many aspects of the traditional economy. Consequently we emphasize that our estimates should be considered preliminary and that more detailed studies need to be undertaken to better understand the sensitivity of harvesting to fossil fuel prices.

Introduction

Remote Indigenous communities, such as those in the Inuvialuit Settlement Region, are economically and socially distinct from the rest of Canada. In these communities, traditional hunting, fishing, and trapping activities provide an important dietary contribution and generate significant non-monetary economic and social value. As a result of their remote location, these communities also have a high cost-of-living and a heavy dependence on fossil fuels for transport of goods, travel, heating, electricity, and fuel for land-based activities.

Carbon pricing has been in effect throughout Canada since 2019, impacting the price of many goods and services, particularly fossil fuels. Further increases in carbon prices are planned for the next several years. While the federal government has committed to avoid a disproportionate burden on Indigenous peoples as a result of carbon pricing, an understanding of how the traditional economies of northern regions will be affected by carbon pricing and a clear plan for mitigating these potential impacts are still lacking.

As a first step in addressing these knowledge and policy gaps for the Inuvialuit Settlement Region (ISR), this report examines the potential impact of carbon pricing on the Inuvialuit traditional economy, focusing on the following questions:

- What is the Inuvialuit traditional economy, and why is it important?
- What is the size of the traditional economy and what is its carbon impact?
- How will carbon pricing impact the traditional economy?

We address these questions through a review of the existing literature on Inuvialuit and Inuit culture, economy, nutrition, and health, and with new analyses using the best available data on hunting, fishing and trapping activities for the six communities in the ISR. The report concludes with recommendations for the implementation of carbon pricing policy in the ISR. Because of the limitations of the existing data, our recommendations include suggestions for future studies that could assist in better estimating the scale of the Inuvialuit traditional economy and how it interacts with carbon pricing.

Status and objectives of carbon pricing in the Northwest Territories

The Pan-Canadian Framework on Clean Growth and Climate Change was implemented in 2019 across Canada as a commitment that Canada would do its part to combat climate change (Government of Canada 2016). A core component of the Framework is the reduction of greenhouse gas emissions by applying carbon pricing to a broad set of emission sources (initially set at \$20/tonne CO_2 equivalent in 2019 and increasing \$10 per year until 2022). The Pan-Canadian Framework provides provinces and territories with the ability to implement their own carbon pollution pricing systems, but contains a backstop system that applies in any province or territory that does not have a carbon pricing system in place that aligns with the federal targets (Environment and Climate Change Canada 2017). All funds collected by the federal government are returned to the governments of provinces/territories that have programs in compliance with the federal policy; while for jurisdictions falling under the federal backstop, 90% of funds are paid out to residents as Climate Action Initiative payments, and the remaining 10% are paid to Indigenous groups, the education sector, small business and municipalities (Department of Finance Canada 2021). In 2020, the federal government laid out more ambitious greenhouse gas emission targets, aiming for net-zero emissions by 2050. Under this new plan, after 2022 carbon prices will increase by an additional \$15/tonne CO_2 per year to a total \$170/tonne CO_2 in 2030 (Government of Canada 2020b).

While committing to carbon pricing as a central component of Canadian climate change policy, the federal government also committed to "work with the territories to find solutions that address their unique circumstances, including high costs of living and of energy, challenges with food security, and emerging economies." (Government of Canada 2016). Avoiding a disproportionate burden on vulnerable groups and Indigenous peoples is also a guiding principle for the implementation of carbon pricing under the Pan-Canadian Framework.

In the Northwest Territories, the territorial government (the GNWT) is currently implementing a "made-in-the-North" approach to carbon pricing that meets the 2016 federal requirements (prices beginning at \$20/tonne CO_2 in 2019 and increasing to \$50/tonne CO_2 by 2022). Components of the GNWT plan intended to mitigate the impacts of carbon pricing on NWT residents include: a carbon tax exemption for aviation fuel, a 100% rebate on additional costs to heating fuel, a rebate to the Northwest Territories Power Corporation to offset electricity production costs, and a cost-of-living offset benefit paid to residents, increasing to \$260 per adult and \$300 per child by 2023 (Government of the Northwest Territories 2018). It is not yet clear how the federal government's more recent net-zero target—and accompanying higher carbon prices—will be implemented in the NWT.

The existing GNWT plan also does not account for the impact of carbon pricing on the traditional economy in the ISR. As we show in this report, millions of dollars worth of goods and services are produced by the Inuvialuit Traditional Economy each year, but this value is largely invisible to federal and territorial government statistics due to its non-monetary nature. However, traditional economic activities, including hunting, fishing, and trapping (HFT), rely on fossil fuels for transport and warmth on the land, as well as on a wide range of imported supplies. While the GNWT is fully subsiding heating and electricity costs for NWT residents, transport fuel costs—i.e., gasoline used for hunting, fishing, and trapping in the ISR—are not exempt from the tax, nor are indirect costs to other necessary harvesting supplies (e.g., increased prices for snowmobiles and other equipment). Under the current GNWT plan, these costs would have to be absorbed by Inuvialuit families, potentially impacting their ability to afford HFT equipment and supplies. General increases in the cost-of-living in the ISR could also impact the traditional economy if households are forced to divert funds away from HFT towards other necessary expenses.

Accordingly, carbon pricing needs to be deployed carefully in the ISR. To date, the Inuvialuit Regional Corporation (IRC) has completed two Phases of a Carbon Pricing Impact Study to better understand how carbon pricing will impact households in the ISR. This third phase report focuses on explaining the Inuvialuit Traditional Economy, estimating its value, and examining how it may be impacted by carbon pricing.

What is the Inuvialuit traditional economy?

The system of relationships, mutual expectations, norms and institutions that, today, reliably brings imported goods across the world to Inuvialuit communities—the global market economy—is built around the exchange of money. However, in Inuvialuit communities, alongside the well-measured cash economy, there exists a traditional non-market economy which, while culturally and economically important, is poorly documented by existing public sources of data. Though this system is less readily measured than flows of cash, there is nevertheless a robust academic literature documenting (1) the history of traditional economies among Inuit, (2) the coexistence of Inuit traditional economies with wage economies, and (3) the cultural, personal and economic costs and benefits of participation in traditional economic activities.

This section reviews published evidence related to the history and contemporary form and function of the Inuvialuit Traditional Economy. Though we draw on evidence from throughout the Canadian Arctic, the conclusions we draw are applicable to the ISR. We do not review the international literature in detail, but note that the persistence of traditional economies alongside market economies has been documented in observational longitudinal studies around the world, including in Greenland, Russia, Alaska, and Bolivia (Poppel and Kruse 2009; BurnSilver et al. 2016; Gurven et al. 2015). However, the stability of these "mixed" economies depends on the circumstances, as cash economies can also undermine traditional economies and erode the social capital they produce (Kasper and Borgerhoff Mulder 2015).

Historical origins and 20th century change

Prior to the settlement era, hunting and fishing were the basis of Inuit economies. Cooperation and sharing were a vital part of Inuit adaptation to Arctic conditions, and have been for thousands of years. Archaeological evidence from the Old Bering Sea culture on the north coast of Alaska, which dates back to 300 A.D., shows a whaling-based economy that could only have functioned with extensive inter-household coordination and distribution of food (Mason 1998; Mason and Rasic 2019). The Old Bering Sea culture is a potential ancestor, at least technologically (Mason 2016b), to the Birnirk culture in Alaska and Siberia whose peoples are the genetic ancestors of Inuit (Raghavan et al. 2014).

Early anthropologists and explorers throughout the North American Arctic documented hunting practices and food sharing customs within Inuit villages (Boas 1885; Stefánsson 1913; Jenness 1922), demonstrating that hunting and fishing-based economies, and associated sharing practices, persisted through the commercial whaling and fur-trade eras into the early- to mid-20th century. Firearms arrived even in the more remote Inuit territories by roughly 1900, and by 1930 nearly all Inuit hunters used and owned them. During this same period, traditional boats used for hunting, fishing, and travel were replaced with schooners, which were at first powered by sail and later by motor engine. Engine-powered schooners were owned by some Inuvialuit as early as 1912 (Button 2008). These new technologies did alter hunting patterns somewhat—for instance, firearms diminished the need for cooperative caribou drives—but they did not profoundly alter the subsistence-based and cooperative nature of Inuit traditional economies (Balikci 1964; Graburn 1969; Condon 1996).

In the aftermath of the second World War, the economic and social context of Inuit Nunangat (Inuit homelands) was radically and rapidly altered. Lack of ammunition and poor hunting conditions led to dire economic situations in some parts of the Canadian Arctic (Arbess 1966; Duhaime 1983). In response to these conditions, the Government of Canada greatly expanded its role, providing family allowance payments and housing to Inuit—but also enforcing school attendance for children, including, in some cases, at residential schools. In the Inuvialuit region, there were two residential schools established at Aklavik by 1951 (Damas 2002). Some aspects of the settlement process during this period were voluntary; for instance, DEW-line construction projects in the 1960s brought new employment opportunities and resources to some locations, leading Inuit to congregate there. Other aspects of the process were coercive (Damas 2002), and many Inuit and scholars link ongoing social problems in Inuit communities today to abrupt changes that occurred during this period (e.g., Qikiqtani Inuit Association 2013; Rasing 2017).

Nevertheless, the subsistence economy persisted through the settlement period, as traditional foods remained more affordable and culturally important, and opportunities for wage labour remained scarce (Vallee 1968; Graburn 1969; Wenzel 1981). However, hunting patterns changed substantially as a result of permanent settlement. In particular, snowmobiles soon replaced dog teams as the primary means of transport for hunting in the ice-covered season (Wenzel 1981), for complex reasons: there were outbreaks of rabies and canine distemper, attacks by poorly fed dogs, some Inuit killed or abandoned their teams because they were forced to relocate or took up employment, and many dogs were shot by the RCMP (Qikiqtani Inuit Association 2013). This shift was also driven by the need to travel increased distances to hunt from centralized settlements. Modern Inuit settlements are often located in places that were convenient for fur traders, missionaries, or government officials, rather than in good hunting locations (Damas 2002). For example, in the ISR, Ulukhaktok became a settlement because of the protected deep water harbour that was convenient for Hudson's Bay traders (Usher 1965; Condon 1994).

These changes in settlement patterns and modes of transportation meant that hunters became more dependent on the wage economy to obtain the equipment needed for hunting (Stevenson 1997). With the invention of a commercial method for seal fur processing in 1962, the price for seal furs increased, a development that allowed many Inuit hunters to make a living through the sale of furs (Wenzel 1989). This era was short-lived, however, as the seal fur trade collapsed due to the anti-sealing campaigns that culminated in the 1983 seal fur ban by the European Economic Commission (Wenzel 1991). Since the collapse of the seal fur trade, dependence on the wage economy to access hunting equipment and supplies has continued to increase (Collings 2011; Wenzel et al. 2016).

Despite these changes, subsistence activities including sharing remain economically important and culturally salient in communities throughout Inuit Nunangat, as documented by considerable recent anthropological research (e.g., Searles 2002; Usher 2002; Collings 2014; BurnSilver et al. 2016; Ready and Power 2018), and in Inuit representations of themselves (e.g., the 2016 film "Angry Inuk" by Alethea Arnaquq-Baril). We explore the nature and form of contemporary traditional Inuit economies in the following section.

It is important to emphasize that the changes of the past century cannot be reversed, though work needs to be done to mitigate the on-going negative impacts of these rapid changes, as evident in the reports of government commissions and Inuit testimonies (e.g., the Truth and Reconciliation Commission of Canada, the Qikiqtani Truth Commission), as well as in scholarly work (e.g., Rasing 2017, Kral 2019). Under modern land claim agreements, such as the Inuvialuit Final Agreement (IFA), Inuit beneficiaries are entitled to access to education, health services, and other modern amenities at the same time as they desire and are entitled to pursue traditional hunting, fishing, and trapping activities. The protection of harvesting rights is a central feature of Inuit land claim agreements. Carbon pricing has the potential to lead to harvest losses in the Inuvialuit Settlement Region, and accordingly, the impact of this environmental protection measure on Inuvialuit needs to be evaluated.

In summary, traditional economies based on the redistribution of hunted and fished resources have allowed Inuit and their ancestors to coordinate their actions and dynamically respond to challenges such as long winters and food shortages for millenia. Far from replacing the traditional economy, the modern cash economy has been integrated into Inuit ways of living, supplementing and coexisting with traditional activities and relationships (Wenzel 1995; Usher 2002; Collings 2014; Ready and Power 2018). The historical overview conducted here highlights a scholarly consensus that reliance of contemporary Inuit subsistence activities on fossil fuels is the combined result of externally-imposed settlement policies and of Inuit adapting their traditional practices to changed social and economic conditions. The reliance of contemporary hunting, trapping, and fishing on modern technology does not mean that these activities are not "traditional" nor does it reduce their cultural value (Wenzel 1991).

The contemporary Inuvialuit Traditional Economy

Inuvialuit have a traditional economy that persists today, whose foundation is the sharing the products of hunting, fishing and trapping, and which represents a large fraction of Inuvialuit economic activity. Here we review work by contemporary anthropologists, whose work provides insight into the current form of the Inuvialuit Traditional Economy (ITE) and how it interacts with the market economy. Again, we draw on studies conducted throughout Inuit Nunangat which are relevant to the Inuvialuit case. Then, we review some of the main ways that the ITE produces value, including: (1) providing fresh local food that enhances food security and nutrition; (2) building trust and social capital; and (3) promoting physical, mental, and cultural well-being. We note that in this section, we leave aside estimates of the size and scale of the ITE, as providing current estimates is one of the main goals of later sections of this report.

Inuvialuit engage in a wide range of harvesting on land and on the water. According to the 2018 Inuvialuit Harvest Survey, communities in the ISR harvested over 50 different species, including a wide variety of birds, fish, and land and sea mammals. The set of animals that constitute the core focus of harvesting activities varies between communities due to differences in ecological setting. The vast majority of animals harvested are used for food; those that are not are predominantly small carnivores (e.g., fox, mink) whose furs are sold through the Genuine Mackenzie Valley Fur Program (run by the GNWT), or occasionally to Northern Stores. By-products of harvesting for meat include bone, teeth, antler, horn, and pelts, which are also often used as raw materials by Inuvialuit artists and seamstresses. Berry-picking is also a seasonally important activity (Boulanger-Lapointe et al. 2019).

Hunting, fishing, and trapping activities rely on snowmobiles in the snow-covered seasons, and on all-terrain vehicles (ATVs, referred to locally as "Hondas") and motorboats in the summertime. As detailed in the previous section, these vehicles have been essential to Inuit subsistence activities for decades, and over a century in the case of boat engines. Electric vehicles that could potentially replace fossil fuel-powered vehicles used for subsistence are in development or have recently come on to the market (Nymann Rud et al. 2018). For instance, Canadian company Taiga Motors has developed an electric snowmobile, planned for release in 2021(taigamotors.ca). However, it is not likely that these vehicles will be safe or viable alternatives for Inuvialuit hunters in the immediate future, given their limited range (maximum 140 km for Taiga Motors' model with the largest battery capacity) and the conditions of use by Inuit hunters (e.g., long distance trips, pulling sleds potentially weighing several hundred kilograms, no access to dealers for repairs). Because of the reliance of harvesting equipment on motor-vehicles and gasoline, Inuit hunters today require a substantial amount of money to finance their hunting activities. Considerable research, both within Inuit Nunangat broadly and in the ISR specifically, demonstrates the constraints that dependence on cash places on Inuit hunters (e.g., Usher et al. 2003; Lambden et al. 2006; Ready 2016; Ready 2018a; Ready and Collings 2021).

The production of country food within Inuit communities is highly variable among households. In 1987, Robert Wolfe of the Alaska Department of Fish and Game noted that in the Alaskan communities he studied (including Katovik, an Iñupiat village), 30% of households tended to produce roughly 70% of the community harvest. He termed these high-producers "super-households." Subsequent research has confirmed the same phenomenon—that a relatively small proportion of households produce the bulk of the traditional harvest—in many Indigenous communities in northern Canada (e.g., Natcher 2015), including in the ISR: for instance, Wesche et al. (2018) found that 20% of households in Paulatuk harvested roughly 50% of the total harvest by weight. Large differences in the productivity of households are also apparent in Collings' long-term research with hunters in Ulukhaktok (Condon et al. 1995; Collings 2011; Collings 2014; Collings et al. 2016).

Part of the uneven distribution of harvest production in Inuit communities today can be linked to the need for cash to obtain hunting equipment and supplies. For example, Ready (2018a) found that in Kangiqsujuaq, Nunavik, most high-production households were households where two household heads had regular employment income. These dual-income households had considerably higher total and per capita incomes than other household types. However, financial means cannot completely explain the "super-household" phenomenon. One particularly important additional factor is household demographics.

Mature households with ample labour as well as cash are more likely to be high-producing households (Wolfe 1987; Duhaime et al. 2002; Ready 2018a). For instance, middle-aged or older parents may be able to subsidize the hunting activities of teenage or adult children in their household—these individuals may be technically unemployed but in fact may be highly productive in the traditional economy. Such mature households may function as the centrepoint of food sharing and other kinds of economic exchange among large, multi-household kinship groups (Wolfe 1987; Harder and Wenzel 2012). Importantly, the economic activity of these households is not focused on the accumulation of material wealth or capital within the household. Instead, production is distributed within kinship groups or even more widely (Wenzel 1995; Usher et al. 2003; Ready and Power 2018). For these reasons, "super-households are essential to the well-being of the community as a whole" (Usher et al. 2003: 184). Although *ilagiit* (extended family) structures and the coordinating role of the *ihumataaq* (family leader) are not as important in some parts of the ISR as in the Baffin region, substantial inter-household cooperation and inter-household differences in production are nevertheless present (Berkes and Jolly 2001; Collings 2011; Wesche et al. 2018).

Table 1: Food insecurity in the Inuvialuit Settlement Region (USDA method)

Food insecurity	Aklavik	Inuvik	Paulatuk	Sachs Harbour	Tuktoyaktuk	Ulukhaktok	**ISR total**
Secure/marginal	45.5	58.4	27.4	74.8	38.4	45.2	**49.6**
Moderate	38.4	27.2	59.4	13.6	38.2	27.0	**32.8**
Severe	16.2	13.6	13.1	11.6	22.8	27.8	**17.1**
Not stated	0.0	0.9	0.0	0.0	0.6	0.0	**0.5**

The products of hunting and fishing are not only consumed within the households of harvesters but also widely distributed. This distribution generally involves sharing rather than selling food for cash. Food sharing was a part of the Inuit traditional economy, mentioned by numerous early explorers and anthropologists (e.g., Boas 1885; Stefánsson 1913; Jenness 1922); and was a major focus of interest in classic Inuit studies (e.g., Saladin d'Anglure 1967; Damas 1972). Like harvesting generally, food sharing has persisted to the present day, and recent ethnographers visiting Inuit communities have documented it in detail, including in Nunavut (Harder and Wenzel 2012), Nunavik (Gombay 2005; Ready and Power 2018; Ready 2018b), Nunatsiavut (Dombrowski et al. 2013), Alaska (Bodenhorn 2000; Baggio et al. 2016), Greenland (Dahl 2000), and the ISR (Collings 2011; Collings et al. 2016; Wesche et al. 2018). Scholars have argued that sharing is a core precept of Inuit identity, morality, and philosophy (Searles 2002; Gombay 2010; Leduc 2006), a form of generalized insurance against the chaotic effects of climate change (Ford et al. 2008; Pearce et al. 2010), a mediator of food insecurity (discussed below), or a form of reciprocal insurance for hunters (Ready 2018b). However, sharing is sensitive to economic circumstances: households with higher incomes and with higher food harvests tend to give more away than others (Collings et al. 2016; Ready 2018a; Ready and Power 2018; Wesche et al. 2018). Food sharing also has benefits beyond the simple redistribution of calories. We discuss how food sharing produces social capital within Inuit communities and has benefits for Inuit health in subsequent sections.

In summary, traditional harvesting remains an important economic activity in the ISR, and harvested foods are widely shared, but harvesting participation is highly variable among households. Both the variation in participation in harvesting across households and patterns of food sharing are critical for understanding food access and food security in Inuit settlements today, as well as for households will be affected by carbon pricing. As noted by Wolfe (1987), because of the economic specialization of certain households and the redistributive nature of the traditional economy, policies that are designed without respect to the social reality of rural northern villages may be unnecessarily harmful. For instance, interventions targeted at individuals or households may fail to account for the fact that a large portion of what hunters catch is consumed outside of their own household.

Contribution of the traditional economy to food security, nutrition and physical health

Food security is defined as "access by all people at all times to enough food for an active, healthy life," while its opposite, food insecurity, can be defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in culturally appropriate ways" (Bickel et al. 2000:6). Rates of food insecurity in the ISR and Inuit Nunangat are extremely high, as demonstrated by substantial research over the past decades (Lawn and Harvey 2004;

Egeland 2011; Rosol et al. 2011; Huet et al. 2012; Canadian Council of Academies 2014; Ready 2016; Galloway 2017; Kenny et al. 2018a; and others). Data from the 2017 Aborginal Peoples' Survey suggest that 49.9% of Inuvialuit were moderately to severely food insecure (see Table 1). In contrast, only 8.8% of Canadian households experienced moderate to severe food insecurity in 2017/2018 (Statistics Canada 2020), meaning food insecurity rates in the ISR are nearly 5.7 times higher than in Canada as a whole.

An important contributor to the high rates of food insecurity in the ISR is the high cost of imported foods despite federal subsidy programs. A 2017 report found the Nutrition North Canada subsidy program to be both ineffective and lacking accountability mechanisms (Galloway 2017). Despite recent changes to the Nutrition North program, the difference in the affordability of food between Arctic communities and southern Canada remains extreme. For example, the average cost of a food basket (one week of nutritious food for a family of four) in Aklavik, Paulatuk, and Ulukhaktok in March 2019 was $460.47 (Government of Canada 2019; data from Sachs Harbour not available, Inuvik and Tuktoyaktuk are not eligible for full subsidies from Nutrition Northern Canada). In comparison, the price of a weekly food basket in Edmonton during the same period was $242.80 (Government of Alberta 2019). Kenny et al. (2018a) found that "the average price of the most frequently consumed market foods, based on the 24-h recall of the IHS [2007–2008 Inuit Health Survey] (i.e. milk, butter, bread, pasta, potatoes, and cola), were 41%, 42%, 51%, 179%, 256% and 470% higher, respectively, in the ISR relative to the national average."

Based on results of the 2007–2008 Inuit Health Survey, Kenny et al. (2018b) found that the dietary contribution of traditional foods in the ISR was roughly 16% of total calories, but varied by age and gender (Table 2). Across three Inuit regions examined by Kenny and colleagues, (the ISR, Nunavut, and Nunatsiavut), average country food consumption ranged from 6.9 to 19.6% of total daily calories. An earlier study by Kuhnlein and Receveur (2007), based on data collected in 1998–1999, found that community averages in the same regions ranged from 13 to 40%. Overall, rates of country food consumption among Inuit are variable: both between genders (with men consuming more than women), across ages (older Inuit consuming more than younger Inuit), and across socioeconomic status (with poorer households consuming more traditional foods) (Lawn and Harvey 2004; Kuhnlein and Receveur 2007; Sheehy et al. 2015).

Traditional foods also make a contribution to Inuit nutrition that surpasses their caloric importance, because they are generally high in protein, healthy fats, and other nutrients (Kuhnlein et al. 2002). For example, Kenny et al. (2018b: 1319) found that "country foods represented a major source of protein (23–52%), Fe [iron] (28–54%), niacin (24–52%) and vitamins D (up to 73%), B6 (18–55%) and B12 (50–82%)" consumed by Inuit in the ISR, Nunavut, and Nunatsiavut. In addition to the nutrients mentioned above, Kuhnlein and Receveur (2007) found that consumption of traditional foods also increased daily intakes of vitamin E, riboflavin, vitamin B-6, iron, zinc, copper, magnesium, manganese, phosphorus, potassium, and selenium.

Table 2: Contribution of traditional foods to total energy consumption in the ISR, based on data from the 2007–2008 Inuit Health Survey (Kenny et al. 2018b).

	Women	Men	Total
Participants <40 years	6.0	8.1	6.5

Participants 40 years and older	17.8	21.7	19.2

The considerable nutritional impact of traditional food intake can be linked to the fact that store foods consumed by many Inuit are often of low nutritional value, partly because of the high cost of nutrient-dense store foods such as meat, fruits, and vegetables in Inuit communities, combined with high rates of poverty Kuhnlein and Receveur 2007; Gombay 2010; Huet et al. 2012; Kenny et al. 2018b). Store foods of similar nutrient value to country foods are thus often unaffordable for Inuit, while low-nutrient (but often high-calorie) foods are much cheaper (Kenny et al. 2018a). This has important health implications, dietary transitions towards a high intake of non-nutrient-dense foods with high fat and/or sugar content is linked to food insecurity, obesity, cardiovascular disease and diabetes among Inuit (Kuhnlein et al. 2004; Chateau-Degat et al. 2010; Hopping et al 2010; Egeland et al. 2011; Zienczuk et al. 2012; Bruce et al. 2014; Sheehy et al. 2015).

The role of traditional foods in supporting Inuit food security is critically maintained by the redistribution of traditional foods: sharing provides a buffer to household food security through flows of resources from high-to low-producing households (e.g., Harder and Wenzel 2012; BurnSilver et al. 2016; Wesche et al. 2018). For instance, Ready and Power (2018) show that the Gini index of food receiving in Kangiqsujuaq (Nunavik) is lower than the Gini indices of food giving and food harvesting; suggesting that food sharing reduces inequality in food access between households. However, extensive sharing is particularly linked to households with the means and manpower to sustain high levels of harvest production (Harder and Wenzel 2012; BurnSilver et al. 2016; Ready 2018a), and food sharing networks may be vulnerable to the disappearance of these households (Baggio et al. 2016). In addition, not all food insecure households have equally good access to country food through sharing (Duhaime et al. 2002; Collings et al. 2016; Ready 2018b).

In summary, food insecurity in Inuit communities is mediated through a complex interaction of social and kinship ties, patterns of harvest production, and socioeconomic status. Considerable research points to the importance of promoting access to traditional foods for promoting Inuit food security (e.g., Ready 2015; Hoover et al. 2016; Kenny et al. 2018a). Dietary transitions resulting in a decrease in the consumption of traditional foods among Inuit may have major costs in terms of food insecurity, population health, and the provision of health services. As argued by Sharma (2010: 7) in a review of diet and lifestyle in the Canadian Arctic: “From a health systems perspective, investing in chronic disease prevention programmes is essential if the territories are to adequately and sustainably manage health care costs in the long term.” Protecting Inuit traditional economies is one means of investing in the prevention of chronic diseases such as heart disease and diabetes.

Contribution of the traditional economy to social capital in Inuit communities

The harvesting and redistribution of food in the Inuvialuit Traditional Economy also provides value through the social ties it creates and reinforces. As noted previously, the primary objective of production in the Inuit traditional economies is not the accumulation of wealth for personal use, but rather “the ends of economic activity tend to be inseparable from the social system, and are more likely to be the maintenance of the system of social relations” (Usher et al. 2003: 179). Numerous Arctic scholars have made similar arguments about the primacy of social relations in Inuit traditional economies (Condon et al. 1995; Wenzel 1995; Ready and Power 2018). Hunting and fishing, camping and travelling on the land, the preparation, sharing, and consumption of traditional foods, and even repairing equipment are often cooperative and/or social activities, in addition to sometimes being (non-monetary) economic transactions themselves. The social ties forged and strengthened through these activities generate a form of social insurance for households and build social capital in Inuvialuit communities.

A particularly informative and relevant example is provided by Collings (2011), who mapped the social networks of hunters in Ulukhaktok. He found that full-time hunters had larger social networks in comparison to wage-earners who also engaged in subsistence production. While wage-earners tend to solve problems (e.g., a broken snowmobile) with cash, full-time hunters "preferred to solve problems using their social networks. That is, food giving to collaterals and distant collaterals is part of a much more significant movement of goods, involving the free flow of snowmobile and ATV parts, tools, sleds, labor, and other favors" (Collings 2011: 8). Thus, cash-poor hunters—who are often "unemployed" in the wage economy—were nevertheless able to access the equipment and supplies needed to sustain high levels of productivity in the traditional economy. The deeply social economic strategies of full-time hunters also provided them with better access to information about current hunting conditions than wage earners.

The social networks generated through traditional economic activities also generate resilience to economic, social, and ecological shocks in Inuit communities (Berkes and Jolly 2001; Baggio et al. 2016). For instance, information sharing among hunters helps them avoid dangerous travel conditions, and can lower search costs and improve hunting returns for highly mobile prey, such as caribou and beluga. On a larger scale, intercommunity trade can buffer local variations in resource availability, for instance, due to fluctuations in caribou herds (Berkes and Jolly 2001; Wesche et al. 2018). Networks of sharing and cooperative hunting also have the potential to adapt to the needs, abilities and experience of their members (Wenzel 1981; Collings et al. 2016).

For these reasons, the investments that households make in the traditional economy can be considered as a form of social capital that provides insurance against future risks (Lin 2001): by sharing food, information, and equipment, households build relationships of trust that can help them deal with future challenges. The value of this social insurance is extremely difficult to measure, however, because it is held in social relations and in their latent capacity to reorganize. The latter capacity means that analyses of network resilience based on static network data (e.g., Baggio et al. 2016; Ready 2018b) may underestimate the ability of traditional economies to respond effectively to change. The study of the dynamics of social support and exchange networks in traditional economies is not yet well-developed, but it is nevertheless clear that weakening these networks would have negative impacts for Inuvialuit. As noted by Collings (2011), if traditional economic networks are reduced in scope (e.g., shrunken into nuclear families), hunters may be less able to respond effectively to new circumstances.

Finally, Inuit traditional economies build trust among community members that enables community projects and decision-making (Dahl 2000). In particular, values that are cornerstones of the traditional economy, including generosity and concern for the needs of others, remain core precepts of Inuit leadership today (Hervé 2015). Similar to how volunteerism might be considered a good quality for local leaders in southern Canada, for Inuit food sharing demonstrates a concern for others and consequently builds trust in community leaders. For example, a recent study in Kangiqsujuaq (Nunavik) found that Inuit from high-harvest households that shared food extensively were more likely to hold elected leadership positions within the community (Ready and Power 2018), a finding that reveals the ongoing role of the traditional economy in Inuit political organization.

Contribution of the traditional economy to Inuit mental health and wellness

Any discussion of the Inuvialuit Traditional Economy is incomplete without a discussion of its contribution to Inuit cultural and psychological well-being. For Inuit, mental health is closely linked to cultural identity and having strong relationships with others (e.g., Kirmayer et al. 2009). According to Inuit Tapiriit Kanatami (2014: 17): "The socio-cultural aspects of harvesting are vital to Inuit well-being since they reinforce a connection with the land that traditionally cultivated Inuit culture, identity, and feelings of self-reliance."

The complex of factors linked to colonialism and the settlement process, including experiences of trauma, alcohol and drug abuse, and disrupted social support networks, are an ongoing challenge for Inuit communities (Rasing 2017; Ready and Collings 2020). Rates of suicide are high among Inuit youth, and this problem has often been linked the aforementioned complex of factors (Kirmayer et al. 1996; Hicks 2007; Kral et al. 2014; Chachamovich et al. 2015; Inuit Tapiriit Kanatami 2016; Affleck et al. 2020). More generally, stress engendered by settlement life provides a potential link between culture change and health among Inuit (Ready and Collings 2018), as people who experience greater stress are at increased risk for poor health (e.g., Sorensen et al. 2009).

Considerable research documents that strong social support networks and cultural engagement are critical protective factors against alcohol abuse and suicide among Inuit in Canada (e.g., Fraser et al. 2015; Morris and Crooks 2015; Kral 2019) and among Indigenous groups in Alaska (e.g., Allen et al. 2014; Wexler et al 2016). As described in the previous section, traditional economic activities provide Inuit with a connection to traditional culture and forge social bonds. The former may reduce stress by promoting cultural congruence, while strong social ties can provide a source of assistance during times of stress (Ayunerak et al 2014; Philip et al. 2016).

Consequently, the health benefits of the Inuvialuit Traditional Economy go far beyond the nutritional benefits of country food. The Inuvialuit Traditional Economy produces benefits to Inuit mental and cultural health without requiring substantial government inputs of money and infrastructure. This contribution is particularly valuable given the high rates of traumatic experiences and suicide among Inuit and the geographic, cultural, and infrastructural barriers they face in accessing health services (Inuit Tapiriit Kanatami 2014; Kielland and Simeone 2014).

To summarize this review, past research reveals the continued vibrance of the Inuvialuit Traditional Economy and several ways that it provides value to both the Inuvialuit Settlement Region and Canada, including by improving food security, building social capital and trust, and promoting Inuit health and wellness. This work makes it clear that the health of the traditional economy is critical to the welfare of Inuvialuit people. However, existing research also documents considerable inequalities in participation in traditional harvesting activities, a phenomenon that is partly driven by the high cost of harvesting in modern settlements.

What is the size of the traditional economy?

Although it is not cash-based, the Inuvialuit Traditional Economy can be understood as an economic system and studied to support evidence-based decision-making about the impacts of policy decisions (such as carbon pricing) on Inuvialuit. However, the Inuvialuit Traditional Economy cannot be fully captured using federal- or NWT-level economic statistics because the NWT profile is skewed by the urban, mostly white, population of Yellowknife and because these activities operate outside of the formal cash-based economic sector. Consequently, a different approach, rooted in more locally-relevant studies, needs to be used to estimate it.

In this section, we draw on a range of sources, including data from GNWT community surveys, Inuvialuit Harvest Studies, Hunter Trappers' Committees (HTCs) in the ISR, and academic studies conducted with Inuit throughout Canada, to estimate the value of the outputs and inputs to the Inuvialuit Traditional Economy. We begin with an overview of current rates of participation in the Inuvialuit Traditional Economy, before proceeding to estimating the quantity of food produced in the ISR through hunting activities. Following past research on Inuit traditional economies, we use the substitution value of similar foods to estimate the value of the products of hunting and fishing (Usher 1976; Brown and Burch 1992; Usher 2002). We then estimate the carbon costs of such substitutions. Finally, we examine inputs to the Inuvialuit Economy and their carbon costs. Throughout the text we highlight key assumptions and limitations of current data and methods.

Participation in the traditional economy

The GNWT Statistics Department's yearly community profile surveys provide the most recent, albeit coarse-grained, picture of the rates of participation in the traditional economy in the ISR. Table 3 summarizes participation rates in the traditional and cash economies in ISR communities in 2018, based on the GNWT 2019 community survey, employment data from the 2016 census, and Hunter Trappers' Committee (HTC) membership data from the 2018 Inuvialuit Harvest Study (IHS). The table focuses on data concerning Indigenous residents, as non-Indigenous residents of the ISR generally have different demographic and socio-economic characteristics and are often only transient residents (e.g., teachers and nurses). It should be further noted that Inuvik is a regional administrative center with different economic, educational, and social opportunities than the smaller communities, which contributes to the somewhat lower harvest participation rates there.

Outside of Inuvik, rates of participation in traditional hunting and fishing are higher than rates of participation in wage labor. A total of 1,824 Indigenous residents in ISR communities aged 15 and older reported participating in hunting and fishing, 228 participated in trapping, and at least 1,497 engaged in berry-picking. It should be noted that the age, gender, and socio-economic profile of berry-pickers may be quite different to those of hunters; as in many communities berry-picking is an activity that is more accessible to women, to the very young, very old, and those without motorized transport. An additional 1,040 Inuvialuit residents engaged in arts and crafts production.

Subsistence hunting, fishing and trapping and traditional craft production are time- and labour-intensive activities that can take up a large proportion (even all) of many adults' productive hours (e.g., Collings 2011, discussed earlier). More detailed information on time allocation for Inuvialuit with different harvesting profiles would be needed to estimate the total number of hours invested in harvest production in the ISR. However, we can estimate how many harvesters are engaged in harvesting year-round. Usher (2002) suggested that there were 471 active harvesters in the ISR in 1991 based on the number of individuals who reported harvests in the IHS. The total number of Inuvialuit residents aged 15 and older reporting frequent, year-round harvesting in 2018 was 465, while the number of registered HTC members for the same year was 1039 (Table 3).

Table 3: Indigenous traditional activity and labour force participation rates in the ISR. Data from 2018 (2019 GNWT community survey), 2016 census, and 2018 IHS.

	Aklavik	Inuvik	Paulatuk	Sachs Harbour	Tuktoyaktuk	Ulukhaktok
Indigenous population 15+[1]	445	1,746	196	71	668	303
Produced arts & crafts (%)	17.8	26.7	38.3	40.8	31.1	60.1
Hunted and fished (%)	53.0	43.7	74.5	77.5	57.8	78.5
Total participants	236	763	146	55	386	238
Frequently throughout the year	27.5	17.8	41.8	54.5	29.8	24.4
Occasionally more than day trips	44.9	22.5	19.9	14.5	33.9	23.1
Occasionally (only day trips)	4.7	40.9	28.1	27.3	28.0	42.9
Rarely hunts or fishes	22.0	18.1	10.3	x[2]	8.0	9.7
Went trapping (%)	11.9	4.8	7.1	21.1	6.0	7.6
Gathered berries (%)	41.6	40.1	59.2	x	58.1	35.3
Registered HTC members	216	264	71	64	314	110
Households consuming >50% of meat and fish from local harvest (%)[3]	47.2	22.3	79.2	60.0	60.2	67.3
Indigenous employment rate (2016) (%)	43.8	59.8	51.4	64.3	39.3	46.3

1. Indigenous residents in Aklavik and Inuvik include Gwich'in. 2. Suppressed in source due to small sample size. 3. For all households (including non-Indigenous).

Consequently seems fair to suggest that, while the total number of people harvesting in the ISR (1,824) may have increased in past decades (due to population growth), the number of highly active harvesters has stayed roughly the same (cf. Usher 2002; Wenzel et al. 2016). However, it is important not to discount the economic contribution of even occasional harvesters—of all ages and gender (children are excluded from Table 3). For instance, springtime ice-fishing, often a family activity, can produce a very large amount of food.

Though highly active hunters amount to only a small proportion of the population of each community, more than half the households in each community report getting over half of the meat and fish they consume from traditional sources (Table 3). However, the volume of food that this represents is variable.

For instance, households with limited cash availability may purchase very little meat due to its high costs (Kenny et al. 2018b). Nevertheless, traditional foods comprise a substantial proportion of calories consumed in the ISR and make outsized contributions to Inuvialuit nutrition (discussed earlier).

Harvest production

Here, we use data from the 2018 Inuvialuit Harvest Survey (IHS) to estimate quantities of food harvested in the ISR. The IHS is administered locally in each community through the Hunter Trappers Committees. Only members of the HTCs were included in the study, and participation in the study was voluntary. In principle, local interviewers contacted harvesters each month in order to record any harvests, if the harvester had not been active that month, or if they were "out-of-sample" for the month (e.g., moved or away from town).

Estimates of the output of the Inuvialuit Traditional Economy have previously been calculated by Usher, whose early work in the Inuvialuit Region (e.g., 1971, 1976) provided the basis of methods still used today in the analysis of traditional economies. The Inuvialuit Harvest Study Data and Methods Report 1988–1997 (IHS 2003) forms an important starting point for the methods used here. We begin with a discussion of our methods of analysis and the limitations of the data.

In the 2003 IHS decadal report, the analysts were able to use the proportion of harvesters contacted in each month who successfully harvested during that month to extrapolate from the reported harvests to the total harvests in each community. However, while harvester participation rates in the 1988–1997 harvest studies were often 90% or more, participation in the 2018 survey was much lower (closer to 50% on average) and much more variable (ranging from 0 to nearly all harvesters in a month in a village), for a variety of reasons. For example, in some months in some villages, no harvests were reported at all due to a lack of available interviewers. Comments obtained on a community tour conducted by the Inuvialuit Community-Based Management Program in 2018 also described a lack of adequate incentives for harvesters to participate in the IHS (IHS 2019).

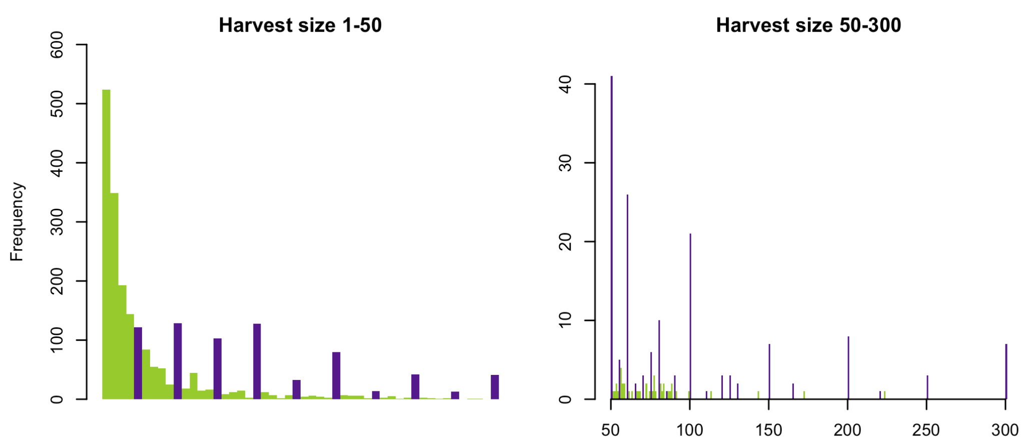
In addition, the IHS data do not provide any demographic details that might allow us to adjust for biases in which harvesters (e.g., active vs. non-active) tended to be included in the sample in a given month. This is by design, as the promise of privacy is intended to increase the trust of harvesters in the process and encourage participation. Biases between respondents and non-respondents could go in either direction. For instance, very active harvesters may not have time to participate in a survey, while non-respondents may think the survey is not important if they have not harvested anything (IHS 2018).

Finally, an additional issue in the 2018 data is that coding of harvesters who did not harvest in a given month was done inconsistently both between villages and through time within villages. Due to these data-quality issues, extrapolating from the reported harvest to an estimate of the total harvest is not straightforward for the 2018 harvest data. In view of this, we focus on calculating the total harvest reported in the IHS, which we take as a minimum estimate for the total harvest that year. At the end of this section, we examine the data on participation rates in the 2018 IHS in order to make suggestions about how much larger the total harvest could be.

Beyond the issue of the representativity and coverage of the sample, there is the question of the accuracy of reports. It has been suggested that some hunters may falsely report no harvest, possibly as a result of survey fatigue, though this problem is likely minor (IHS 2003). Similarly, we think it is quite unlikely that hunters would report harvests that did not actually occur. In our view, the most likely important source of error in the data would be recall bias: specifically that hunters may forget to report some harvests, leading the estimates to be low. Difficulty in recall is perhaps more likely to impact small, unremarkable episodes than large or unusual catches. Unfortunately we have no data with which to assess potential recall bias.

Another important source of error in the data is “heaping,” where harvest numbers are approximated to rough intervals of five, 10, or 100, for example (Vaske and Beaman 2006). This is especially likely for animals harvested in large quantities, such as netted fish or migrating birds, which are unlikely to have been exactly counted by hunters. The upper panels in Figure 1 illustrate heaping in the 2018 harvest data: frequencies of harvest quantities decay smoothly until 10, at which point they spike, and continue to spike at multiples of five up to a harvest size of 100. Beyond harvests of 100 animals, reports are almost always grouped at intervals of 50 and 100.

To deal with the error induced by heaping, for all common targets of heaping in the data (all numbers greater than 9 and divisible by five), we simulate possible “true values” of the harvest by sampling from a normal distribution with the mean centered at the reported value and a standard deviation of 12.5% of the mean. This means that, for example, for a reported harvest of 100 we are 95% certain that the true value lies between 75 and 125. We assume that reports of harvests of less than 10 animals, or that are not multiples of 5, are without error. This procedure produces a smoothed distribution of harvest values resembling that shown in the bottom panels of Figure 1.



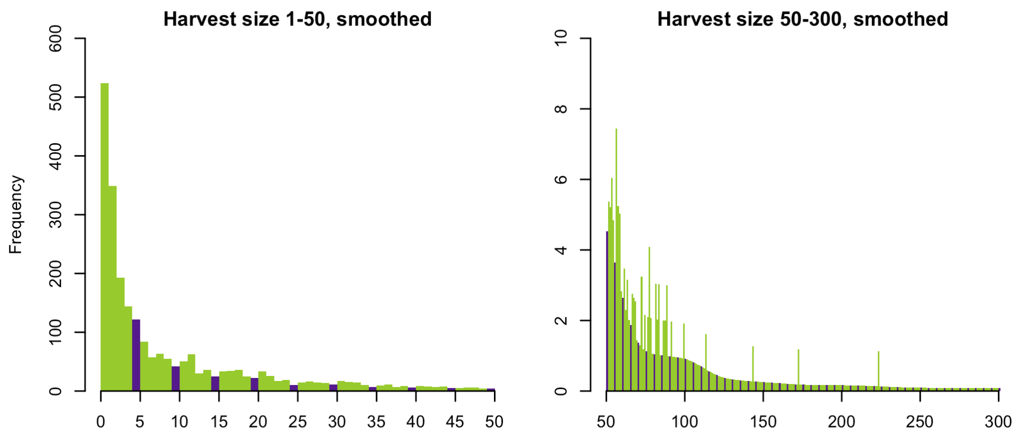


Figure 1: Top: Demonstration of heaping in the harvest estimates, using the 2018 Inuvialuit Harvest Study data. Bars in purple are multiples of 5. Note the difference in the y-axis between the panels. Data in the right-panels are truncated at 300 although there are a small number of larger harvests. Bottom: 2018 harvest data after applying our smoothing algorithm to the heaping points. Note the different y-axis on the right-hand panel. No error was added to harvests reported not as multiples of five.

An additional source of error in the data stems from data entry. For instance, in the 2018 IHS data the code "HarvestNum" referred to the harvester ID number, while "NumHarvest" referred to the number of animals of a given type obtained in a harvesting event, and these fields were not often confused in data entry. Similarly, Spatial ID numbers were sometimes erroneously entered in the HarvestNum or NumHarvest columns. In many of these cases, inspection of the data allowed us to replace the correct Harvester ID. For harvest numbers, we examined the data for clearly unreasonable harvest numbers (e.g., over 3000 moose in a single harvest episode), and flagged these values as missing. We then imputed missing harvest size data by sampling from the distribution of harvest sizes for each species, after the "de-heaping" procedure.

Our method for smoothing heaped estimates, imputing missing data, and calculating the variance induced by these procedures can be summarized as follows. First, for all heaped estimates we sampled from the distributions described, replacing the heaped report with a sampled value. Then, we imputed missing data by sampling from the distribution of harvest sizes for that species (including the de-heaped estimates). We repeated this procedure 10,000 times. Total and village-level harvests and their variance for each animal species or type in the dataset were then calculated by taking the mean and variance of the sum of each of the 10,000 sampled harvests.

Once the quantities harvested are estimated, these need to be converted to edible amounts. To do this, we reviewed three main sources of edible weight data: Usher (2000), who calculated edible weights for species hunted in the ISR; Ashley (2002), who reviewed all available edible weight estimates for hunted game in the NWT and Nunavut; and Brown et al. (2016) who derived new estimates for several fish species taken in Alaska. Our list of edible weight values, including descriptions of calculations for new values, is provided as a supplementary file (S1).

For mammals, we adopt Usher's values, where available, as they are consistently lower and, we believe, more accurate than most estimates reviewed by Ashley (2002). We exclude species primarily harvested for pelts (mainly carnivores, including wolf, wolverine, fox, marten, mink, lynx, and otter, as well as squirrel) from the calculations of edible weights. We note that for beluga we include only the amount of muktuk acquired, as this is generally all that is used for human consumption in the Inuvialuit region.

Three mammals—bear, muskrat, and bearded seal—provide a particular challenge in terms of assessing edible weight because, although they are generally harvested for furs, they may also be eaten with some regularity. Some authors (e.g., Usher 2002) have not included these animals in estimates of the traditional food produced in the ISR for this reason. In the case of bearded seals, which are taken very rarely in the ISR (only eight reported in the 2018 harvest data), they are generally hunted specifically for the purpose of obtaining materials for making traditional skin boots (Peter Collings, personal communication). Although part of the seal may occasionally be eaten, some bearded seals (particularly large males) may be considered entirely inedible and the meat largely used as dog food. Thus we omit bearded seals from our calculation of food value.

Regarding bears, a 2008 report on local and traditional knowledge of grizzly bear indicated that Inuvialuit in Aklavik rarely eat grizzly bear (Wildlife Management Advisory Council (North Slope) & the Aklavik Hunters and Trappers Committee 2008). Thus we do not include grizzly bear in the calculation of edible weights. However, ethnographic evidence suggests that a substantial portion of polar bear meat is consumed in some communities. For instance, in Ulukhaktok, parts of polar bear (especially the feet) are considered a delicacy, and when a bear is caught the meat is distributed to all households (Peter Collings, personal communication). Therefore, we use Usher's (1971) conservative estimate of 114 kg for polar bear.

We also include the food value of muskrats. A 1992 study found that muskrat was among the preferred country foods among Inuvialuit in Aklavik and that households reported eating muskrat an average of 26 times per year (Wein and Freeman 1992). Even at a much lower rate of consumption, this suggests that all muskrats harvest reported in Aklavik in 2018 (the focal point of muskrat harvesting in the ISR) could easily have been consumed.

For birds, we compared Usher's (2000) edible weight values to the midpoint weight of all the bird species in the dataset from allaboutbirds.org, a bird identification resource maintained by the Cornell Lab of Ornithology, multiplied by Usher's conversion factor of 0.7 (originally from White 1953). This method produced edible weight values extremely similar to Usher's, and so we used this method to impute edible weights for birds not included in Usher's dataset. However, we used Usher's values where available as these were often based on studies specific to the ISR. In one case (loon), we used a published value in the literature that was lower than our calculated value.

Finally, for fish, we use Usher's estimates where available, as these are based on locally-relevant data, which are particularly important for fish given considerable within-species variation in size and the selection on harvested size produced by fishing technique (e.g., nets vs. jigging). For char, we use Usher's place-specific estimates for Ulukhaktok, Sachs Harbour, Paulatuk and Aklavik. We use the Aklavik value for Inuvik. We use Usher's Aklavik char estimate (which presumably refers to the smaller Dolly Varden) for land-locked char. No char were harvested in Tuktoyaktuk. Where estimates from Usher were not available, we took edible weight estimates from Brown et al. (2016), who reviewed published estimates for a range of fish species harvested in Alaska. Finally, we derived new values for a small number of species using empirically-derived length-weight equations for those species (available on fishbase.org).

We note that the species referred to as "Arctic Cod" in the IHS is likely actually Greenland cod, called "Ugoq" and generally in the 30–50 cm range (Peter Collings, personal communication). We thus base our estimates for "Arctic cod" on a 40-cm Greenland cod.

It should be noted that, although it is standard practice in the literature on mixed economies in Northern Canada and Alaska, the use of single point estimates (without error) for edible weights of animals is potentially problematic. Harvested animals can be highly variable in size due to factors including age, sex, and season/method of harvest. The portion of harvested animals that is actually consumed also varies widely, as a result of local tastes and habits, transport and storage constraints during harvesting trips, and the condition of the animal. A better approach to estimating edible weights would be to use information on harvested animals to estimate the distribution of harvested animal size and the variability in the portion of the species used. Unfortunately, such information is extremely difficult to collect, and thus Usher's data remain the best basis for the edible weights of many species in the dataset.

Finally no systematic harvest data on berries or other gathered resources (e.g., bird eggs) are available and as such these are also excluded from our estimations even though they may represent substantial quantities of food. We can, however, attempt a ballpark estimate at berry harvests through dietary recall studies from the 2007–2008 Inuit Health Survey. Kenny et al. (2018b) reported an average consumption of 2.2 ± 24 grams of local berries in 24-hr recall data. For approximately 2700 ISR beneficiaries, this would correspond to roughly 5.9 kg of local berries consumed per day. If similar consumption rates occurred for the entire year (berries are frequently frozen and stored), the yearly berry harvest in the region could be as high as 2168 kg. However, the 24hr recall study was conducted between August and October (Saudny et al. 2012), which encompasses the berry season, and so the actual harvest may be lower than this estimate.

Table 4. Estimated 2018 mammal harvest, in number of animals and edible weights, with 95% confidence intervals.

	Harvest			Edible Weight		
Species/Type	Estimate	Conf. Low	Conf. Hi	Estimate (kg)	Conf. Low	Conf. Hi
Marine Mammals						
Beluga	62	-	-	8456.8	-	-
Bearded Seal	10	9	11	-	-	-
Ringed Seal	311	285	337	4046.5	3709.6	4383.4
Polar Bear	21	-	-	2394.0	-	-
Caribou						
Barren Ground	287	282	292	10483.7	10293.0	10674.4
Bluenose	15	13	17	528.1	461.5	594.6
Peary	51	-	-	1479.0	-	-
Porcupine	184	182	186	6808.1	6718.2	6898.1
Union Dolphin	74	-	-	2442.0	-	-
Woodland	7	-	-	410.2	-	-
Other land mammals						

Grizzly Bear	13	-	-	-	-	-
Moose	60	58	62	8416.1	8142.8	8689.4
Muskox	168	164	171	11578.3	11328.7	11828.0
Beaver	622	605	639	8398.3	8166.3	8630.2
Muskrat	1523	1449	1597	1066.1	1014.3	1118.0
Arctic Hare	50	47	53	144.6	136.0	153.2
Snowshoe Hare	701	666	735	700.7	666.0	735.5
Wolf	36	35	38	-	-	-
Lynx	94	85	104	-	-	-
Wolverine	29	-	-	-	-	-
Arctic Fox	268	258	277	-	-	-
Fox (*V. vulpes*)	51	48	55	-	-	-
Marten	310	298	322	-	-	-
River Otter	3	-	-	-	-	-
Mink	63	57	68	-	-	-
Squirrel	1	-	-	-	-	-

Table 5. Estimated 2018 bird harvest, in number of animals and edible weights, with 95% confidence intervals.

	Harvest			Edible Weight		
Species/Type	Estimate	Conf. Low	Conf. Hi	Estimate (kg)	Conf. Low	Conf. Hi
Brant	4	-	-	4.0	-	-
Canada Goose	999	950	1047	1048.5	997.4	1099.6
Greater White Goose	3118	2916	3320	5301.1	4958.0	5644.3
Ross's Goose	38	-	-	35.0	-	-
Snow Goose	4240	4083	4398	7208.6	6940.7	7476.5
Rock Ptarmigan	92	84	100	32.2	29.4	35.1
Willow Ptarmigan	316	304	328	158.0	151.9	164.0
Canvasback	5	-	-	4.3	-	-
King Eider	1162	1098	1227	1511.0	1427.6	1594.5
Common Eider	276	254	298	482.9	445.0	520.7
Mallard	207	178	235	175.7	151.4	200.0
Common Merganser	1	-	-	1.1	-	-
Black Scoter	60	50	71	41.4	34.2	48.7
Teal	3	-	-	0.7	-	-
American Wigeon	40	-	-	22.0	-	-
Trumpeter Swan	4	-	-	28.6	-	-
Tundra Swan	39	-	-	185.2	-	-
Common Loon	11	-	-	12.1	-	-
Sandhill Crane	13	-	-	37.7	-	-
Duck - Unknown	16	-	-	10.7	-	-

Given the limitations described above, our results should be treated with considerable caution. Again, our estimates of the number of animals harvested should be considered as minimum estimates. This is due to the issues related to sampling discussed earlier, as well as the lack of data on gathered resources, fatigue and/or recall issues among harvesters, and the historical relationship between harvesters and wildlife managers which might lead hunters to avoid interviews or under-report harvests (Usher 1987; Collings 1997; Nagy 2004). In contrast, the estimates of edible weights should be taken as the total amount of food available from the estimated harvest given specific assumptions (e.g., average animal weights and zero spoilage) that do not account for biological and situational variability. Tables 4–6 present the estimated harvest and edible weights based on the 2018 IHS data. Supplementary files S2 and S3 provide the harvest and edible weight estimates broken down by species and community.

We reemphasize that the IHS data does not include all harvesters/harvests, that there are missing months of data from some communities, and that we are only incorporating measurement error from heaping and missing harvest values in the data. Despite these issues, the reported harvest totals 122,677±582 kilograms of food (Table 7). The most important food species by edible weight are caribou, broad whitefish, muskox, and inconnu, all of which have harvests totalling over 10,000kg per year. The total reported harvest corresponds to an average of 44.3 kg per resident Inuvialuit beneficiary (based on 2767 Inuvialuit beneficiaries living in ISR communities in 2021; 2018 data were not available); ranging from a high of 95.6 kg per beneficiary in Ulukhaktok to a low of 16.4 kg per beneficiary in Inuvik.

Table 6. Estimated 2018 fish harvest, in number of animals and edible weights, with 95% confidence intervals.

	Harvest			Edible Weight		
Species/Type	Estimate	Conf. Low	Conf. Hi	Estimate (kg)	Conf. Low	Conf. Hi
Arctic Char	2991	2906	3076	4553.2	4419.2	4687.3
Dolly Varden	266	120	412	172.9	77.9	267.8
Land-locked Char	1228	1115	1340	798.0	724.8	871.1
Lake Trout	4292	4155	4429	5579.4	5401.8	5757.1
Northern Pike	266	252	281	585.9	554.2	617.5
Broad Whitefish	7813	7500	8127	12892.0	12375.1	13408.9
Lake Whitefish	1638	1519	1757	2047.4	1898.5	2196.3
Inconnu	4155	3904	4406	10596.2	9956.1	11236.3
Arctic Cisco	311	258	365	99.6	82.6	116.7
Least Cisco	361	332	389	115.5	106.3	124.6
Greenland Cod	267	231	303	130.9	113.3	148.6
Saffron Cod	42	-	-	3.8	-	-
Flounder	144	134	154	72.0	67.2	76.8
Fourhorn Sculpin	167	156	178	15.0	14.1	16.0
Burbot	621	587	655	1185.9	1120.9	1250.9
Salmon	1	-	-	1.7	-	-
Smelt	45	40	50	2.7	2.4	3.0
Pacific Herring	2147	1962	2331	171.7	157.0	186.5

In comparison, Usher (2002) estimated that from 1988 to 1997, the per capita harvest of country food in the ISR was 116 kg/year. More recently, a study in Paulatuk estimated that the total harvest in this community for 2018 was 27,973 kg, translating to an average of 102.5 kg per capita (Mussells 2018). However, the methodology used in the latter report is unclear. Our estimate for Paulatuk is 57.1 kg per beneficiary, however, the monthly response rate in our data from Paulatuk varied between 54-64% of HTC members. Moreover, there was no data from Paulatuk from February. Adjusted by the average response rate in Paulatuk, our estimate would increase to 96.7 kg, even disregarding the potentially missing February data (February is one of the months with the lowest harvest rates).

Table 7. Estimated edible weight of harvests reported in the 2018 IHS, by community and animal type.

	Mammals		Birds		Fish		Total		
	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Per capita
Aklavik	17137.7	150.5	2415.8	58.6	4621.9	185.7	24175.5	247.3	85.7
Inuvik	13748.2	141.3	1726.9	167.6	4626.2	181.9	20101.3	284.1	16.4
Paulatuk	6389.0	0.0	4151.6	63.9	2934.2	84.5	13474.9	104.7	57.1
Sachs Harbour	2029.2	73.3	1261.8	79.1	665.9	64.7	3956.8	126.0	46.6
Tuktoyaktuk	11499.4	64.3	3705.3	77.3	17564.0	335.8	32768.7	350.0	51.0
Ulukhaktok	16549.2	200.4	3039.3	50.4	8611.5	92.6	28200.0	227.0	95.6
Total	67352.6	304.2	16300.8	228.4	39023.8	445.7	122677.1	582.0	44.3

Figure 2 examines the issue of response rates in more detail. The upper panel in Figure 2 shows the proportion of HTC members who were successfully contacted each month. Although response rates are quite variable month-to-month and across villages, these data do not reveal any consistent seasonal bias in response rates. However, there are three months for which there are essentially no data from Inuvik. Overall, the response rates are almost always less than 60% of HTC members, and often even lower, which gives an idea of the potential scaling between the reported and total harvest.

The centre panel in Figure 2 shows the proportion of survey respondents each month who reported a catch. This is potentially revealing about sampling biases. If the survey was capturing a representative sample of active harvesters each month, then we might expect a seasonal pattern to emerge, in which the proportion of harvesters reporting catches increases during the spring and summer and is lowest during the winter. This is to some extent visible in the data from Tuktoyaktuk, but in general is not evident, which suggests that active and inactive harvesters may have had different probabilities of being sampled across months. The bottom panel in Figure 2 shows the total number of harvesters who reported a successful harvest in each month. Here, we note the strong seasonal pattern in the reports from Ulukhaktok.

We highlight trends in two villages that we think are particularly informative about patterns of harvesting in the region and the study sample. First, in Paulatuk, the proportion of harvesters sampled each month was highly consistent (besides the lack of data for February). Although it seems possible that highly active harvesters may have been somewhat undersampled relative to non-active harvesters in this community in some months (Figure 2 centre panel, June and August), it seems that extrapolating from the sample to the total harvest for this village is reasonable. Our previous calculation based on the average response rate across the year yielded a per capita harvest estimate of 96.7 kg.

In comparison, in Ulukhaktok, response rates are inconsistent and decline towards the end of the year (Figure 2, top panel). In fact, after May, 100% of respondents in the Ulukhaktok sample each month reported catches (Figure 2, centre panel). What seems to have occurred is that as the year progressed, only active harvesters were recorded in the survey. However, the number of total harvesters reporting catches in Ulukhaktok shows strong seasonal patterning (Figure 3, bottom panel) on a scale that is more consistent with the experiences of anthropologists working in the region, although rates of participation in spring/summer harvesting are probably even higher than suggested by the data (Peter Collings, personal communication).

Therefore, it seems likely that the low-season data for Ulukhaktok data are a nearly complete sample of active harvesters each month, while spring/summer harvests may be underestimated. We note that the per capita harvest recorded in Ulukhaktok is the highest of the villages at 95.6 kg per beneficiary, an estimate quite similar to the value for Paulatuk we extrapolated earlier. In sum, it seems likely that estimates of roughly 100 kg per capita per year are appropriate low-bound estimates for Paulatuk and Ulukhaktok. In both of these cases these are still probably low estimates for the total harvests, as some active harvesters were probably missed (in Ulukhaktok) or undersampled (in Paulatuk) in some months.

The above discussion highlights the difficulties in extrapolating from the reported to the total harvest: in some communities, the sample is biased towards active harvesters, but this bias varies from month to month due to seasonal changes in harvesting activities and other factors. Nevertheless, to place an upper bound on the possible harvest, we calculate the total proportion of harvesters sampled in each month across all communities, divide the total reported monthly harvest by this proportion, and sum the adjusted monthly harvests to obtain a total estimate of 316,413 kg, roughly 114 kg per ISR beneficiary. This estimate assumes that non-respondents harvested at the same rate as respondents (including in Ulukhaktok, where the sample is clearly biased towards active harvesters). If we adjust the sample proportions for Ulukhaktok to the more realistic assumption that all non-respondents there were inactive, the total estimate is 247,005 kg, or 89 kg per ISR beneficiary.

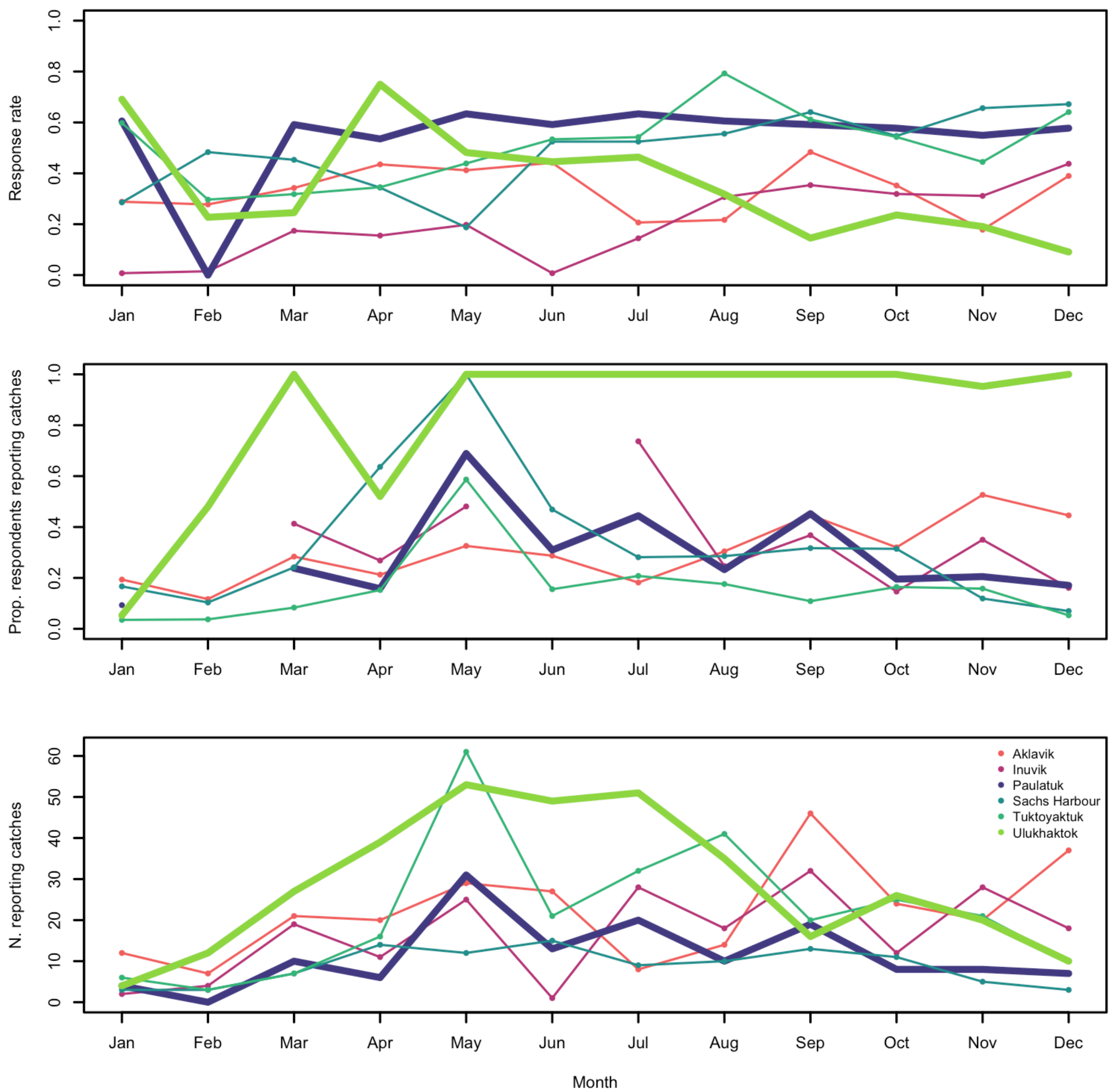


Figure 2. Monthly response rates in the 2018 Inuvialuit Harvest survey. Top panel: proportion of HTC members who responded to the survey each month. Bottom: total number of harvesters who reported catches each month. Lines for Paulatuk (top panel) and Ulukhaktok (bottom panel) are highlighted as the trends in these villages are particularly informative.

In summary, the country food harvest for the ISR in 2018 was at least 122,677 kg and is likely substantially more. Besides the issues already mentioned, a further limitation of our study is that we have only considered one year of harvest data. Examining harvests over multiple years is important, as annual harvests may vary tremendously from year-to-year as a result of fluctuations in weather, animal movements, and other factors (Langdon 1995; Berkes and Jolly 2001). Comments from participants in the 2018 IHS suggest that 2018 was a relatively poor harvest year in the region, especially for fish (IHS 2018).

Substitution value of market products

Having estimated the quantity of food harvested in the ISR, we now turn to estimating its value. To do so, we focus on the market substitution value of harvested foods, following Usher (1976: 105), who argues that "substitution costs provide the most appropriate measure of value [of country foods] and their use is, therefore, recommended." Retail substitution costs are a welfare equivalent, that is, they measure the change in economic welfare of consumers as a result of a change in the market. Usher (1976) argues that welfare-equivalent measures are appropriate for the study of the impact of economic development on wildlife harvesting in northern Indigenous communities, as a result of a conflict between such development and the ability of Indigenous people to freely participate in traditional harvesting. Similarly, Brown and Burch (1992: 232) argue that where society has a responsibility to provide a good (e.g., for equity reasons), "then the value to society of the wildlife unit is as great as the cost of replacing it, since society would incur that cost in the event of lack of availability of the good in question." Although several decades old, these arguments hold in the context of carbon pricing: substantial increases in fuel potentially threaten the traditional harvesting activities of Inuvialuit, activities which are protected under the Inuvialuit Final Agreement. Besides a clear theoretical justification for using substitution value, data for other kinds of value (e.g., the market value) are simply not available.

Thus we focus on the retail substitution costs of market foods, albeit with the "caution that they cannot serve to measure the value of the activity or environment which produces the country food" (Usher 1976: 105). The substitution value of harvested foods excludes any accounting for taste preferences, for instance. Given that most harvest production today is used for food (Usher 1976), we also do not attempt to estimate the value of raw materials for clothing and craft production contributed through harvesting. We note, however, that a large proportion of locally-produced clothing and arts and crafts are used by Inuvialuit (e.g., coats and mittens) or sold on the informal market, and therefore the economic importance of these activities is also likely considerably underestimated in official statistics.

We also do not attempt to estimate the more indirect or less immediately tangible benefits of the traditional economy that were described in the literature review. We are not able, for instance, to specify how the prevalence or severity of food insecurity that could result from decreases in harvesting and/or food sharing, or to determine the increased health care costs that would result from poorer nutrition or poorer mental health in Inuvialuit communities due to decreased participation in traditional activities.

To convert harvested kilograms into retail equivalents, we sum harvests of all species in each village into three categories—mammals, poultry, and fish—and multiply these quantities by the price of similar replacement foods (i.e., relatively unprocessed fresh or frozen meat products) in ISR communities. In consideration of the ways in which traditional foods are processed and consumed, and their high quality and nutritional value, we believe using the cost of high-quality unprocessed cuts of meat and fish provides the most appropriate comparison for country food. However, it should be emphasized that this does not represent what Inuvialuit would actually purchase if country food were not available, as these items would be prohibitively expensive for many Inuvialuit (Kenny et al. 2018b). Nor do these comparisons account for Inuvialuit tastes and preferences; as from this perspective, country foods are irreplaceable. We briefly discuss the potential nutritional impact of reductions in country food availability in the final section of the report.

Our price estimates of the cost per kilogram of replacement foods are shown in Table 8. These estimates are based on average prices reported in each ISR community from an in-store costing study conducted by Kenny et al. (2018b), which established lowest regular prices for preferred purchase volumes of a wide variety of foods. For mammals, we use a mix of 50% pork and 50% beef, based on historical patterns of beef and pork consumption in Canada (Government of Alberta 2017), and consumption data that suggest that Inuvialuit consume relatively similar amounts of pork and beef (Kenny et al., n.d., Supplementary Table 3). We take the average price of the three fresh/frozen cuts of beef in Kenny et al.'s dataset (ground beef, steak, and roast) as the price equivalent for beef, and use pork chops for pork as this is the only type of unprocessed pork in the dataset. We used the price of an even mix of chicken legs and chicken breast as a comparison for birds, and the price of frozen fillets of sole, haddock, pollock, and halibut for fish. The latter was the only item in the dataset that we felt was a suitable comparison for local fish; we considered canned fish, which is considerably cheaper, to be an unsuitable comparison. Finally, Kenny's data were collected between 2014–2016, so we adjust these estimates for the change in the consumer price index of store food between 2016 and 2018 (0.989, Statistics Canada 2021; data for the NWT only available for Yellowknife).

Table 8. Estimated 2018 price ($/kg) of retail substitutes

	Aklavik	Inuvik	Paulatuk	Sachs Harbour	Tuktoyaktuk	Ulukhaktok
Beef and Pork (50/50 mix)	**31.15**	**19.26**	**30.59**	**20.62**	**22.70**	**24.87**
Pork loin, center-cut chops, bone-in	28.64	14.38	27.87	18.33	19.64	24.92
Ground beef, lean	17.27	17.04	12.92	15.24	10.10	19.65
Beef round roast, inside (top)	32.72	27.08	-	22.66	30.30	22.85
Beef steak, inside round	50.96	28.34	53.69	30.8	36.88	31.94
Chicken	**13.91**	**15.08**	**12.59**	**11.20**	**12.36**	**15.72**
Legs	11.71	11.36	8.77	6.73	9.24	13.08
Breast	16.11	18.80	16.04	15.68	15.49	18.35
Fish (frozen fillets)	**29.78**	**21.36**	**17.31**	**33.70**	**33.62**	**41.65**

1. No estimate for beef roast was available for Paulatuk so we used the average across all communities

Table 9. Estimates of total retail value of food harvested in the ISR in 2018.

	Mammals		Birds		Fish		Total		
	Estimate	SD	Estimate	SD	Estimate	SD	Estimate	SD	Per capita
Aklavik	533,838.59	4,688.03	33,604.41	814.96	137,641.21	5,530.87	705,084.21	7,316.54	2,500.30
Inuvik	264,789.59	2,720.98	26,041.94	2,527.39	98,815.70	3,886.35	389,647.24	5,366.82	317.56
Paulatuk	189,817.19	0.00	52,268.87	804.79	50,791.79	1,462.22	292,877.86	1,652.06	1,241.01
Sachs Harb.	41,841.20	1,511.07	14,131.72	885.61	22,440.04	2,179.06	78,412.96	2,804.35	922.51
Tuktoyaktuk	261,036.20	1,460.56	45,797.21	955.67	590,502.40	11,288.31	897,335.82	11,418.73	1,397.72
Ulukhaktok	411,577.95	4,983.00	47,778.47	792.58	358,670.25	3,855.16	818,026.68	6,379.00	2,772.97
Total	1,702,900.73	7,665.45	219,622.63	3,218.58	1,258,861.40	13,916.00	3,181,384.76	16,138.76	1,149.76

Table 9 summarizes the total estimated replacement value of food reported in the 2018 IHS. Our total estimate for the value of the reported harvest is approximately 3.18 million dollars. This corresponds to roughly $1150 per Inuvialuit beneficiary living in the ISR, ranging from $318 per beneficiary in Inuvik and $2,773 per beneficiary in Ulukhaktok. Again, these estimates are based only on the amount reported in the 2018 IHS and are thus a low bound for the total harvest in the region. The adjusted higher bound estimate we calculated previously (247,005 kg) would be worth roughly 6.4 million, using the average price per kilogram in our sample. In comparison, Usher (2002) estimated the replacement cost of traditional harvests in the ISR from 1988–1997 to be $3.35 million annually, or $1150 per capita. Usher used a $10/kg food cost, which adjusted for inflation would be $14.65/kg in 2018. Thus his estimate would correspond to $4.91 million in 2018. Our average price per kilogram of country food across the ISR is $25.93, which is considerably higher than Usher's value. However, we believe that our cost estimate is more appropriate, as it is based on recent cost data for unprocessed meat products in the ISR.

Given the high cost of importing food, the more remote communities also receive subsidies from the federal government to offset these costs. Subsidies for transport of frozen and fresh meat by food mail (see the following section) to Aklavik, Paulatuk, Sachs Harbour, and Ulukhaktok are currently $5.75, $4.95, $7.25, $5.65 per kilogram respectively (Government of Canada 2020a). Replacing country foods in these communities with market foods would therefore not only entail the replacement cost that Inuvialuit would pay at the store—described above—but a considerable additional premium paid by the government. At the current subsidy level, the amount of food reported in the IHS for these villages would result in an additional cost of $393,727.

Having estimated the substitution value of food produced in the ISR, we now briefly turn to estimating incomes from trapping activities in Inuvialuit communities. To do this, we use data obtained on fur sales from the Genuine Mackenzie Valley Fur Program (GMVF). In 2017/2018, 156 residents of communities in the ISR sold furs to the GMVF Program, while 228 Indigenous residents of the ISR reported that they participated in trapping in the 2018 GNWT Community Survey (these figures include some Gwich'in hunters in Aklavik and Inuvik). The number of trappers selling furs in the Beaufort-Delta region, which includes the ISR, has remained relatively stable since 2011, and during this period ISR trappers have constituted an average of 83% of trappers in the Beaufort-Delta region (range 81–87%).

For 2018–2019, fur sales from NWT totaled $731,385.42, and furs from the Beaufort-Delta constituted roughly 30% of the total sales in the NWT. This would correspond to approximately $182,115 in fur sales from the ISR, although due to the GMVT subsidy program the income received by trappers would be higher (in 2017/2018 trapper incomes were 173% of fur sales). This number further does not include incomes from selling furs to Northern Stores. The value of untanned skins used in the production of traditional clothing is also unaccounted for.

In summary, we estimate that the replacement value of food reported in the 2018 Inuvialuit Harvest Study and fur production in the ISR in 2018 was at least 3.36 million dollars. The harvest reported in the IHS also saved nearly $400,000 in food subsidy costs. However, the total harvest likely substantially exceeds our minimum, and could be worth over 6 million dollars.

Carbon costs of market substitution

We now attempt to estimate the cost of market substitutes to harvest production in the ISR in terms of greenhouse gas emissions; that is, to quantify the emissions avoided due to the consumption of country food. An important consideration in calculating greenhouse gas emissions is whether only direct emissions need to be accounted for, or whether indirect emissions also should be included. Direct emissions result from the industry itself, while indirect emissions incorporate emissions from inputs to the industry as well (Pandey et al. 2011). For example, in the case of beef production, an approach incorporating indirect emissions would include not only the emissions from the cattle industry itself (e.g., methane emitted by cattle), but also the greenhouse gas emissions resulting from the agricultural industry dedicated to feed production. In assessing the emissions resulting from substituting traditional foods with market substitutes, it is our view that a comprehensive life-cycle approach that includes indirect emissions incurred in the production of food is most appropriate.

Point estimates of greenhouse gas emissions "to the farmgate" or to the point of carcass processing for livestock industries in Canada have been calculated for beef, pork, and poultry in a number of papers (Vergé et al. 2008, 2009a, 2009b, 2016, 2018; Desjardins et al. 2012; Mackenzie et al. 2015; Legesse et al. 2016). The most recent year included in these studies was 2006 for poultry, and 2011 for beef and pork. More recent data on agricultural greenhouse gas emissions are available from the Government of Canada (e.g., Environment and Climate Change Canada 2020), however, only estimates of direct emissions for livestock production are provided in these reports and as such these data are not suitable for our purposes. Consequently, for beef, pork, and poultry we take the most recent western Canadian estimates from the published literature (Table 10).

The adjusted estimates in Table 10 estimate total carbon emissions of meat production through to the delivery of a packaged product to retail distribution centres. To calculate these values, we convert published estimates (per kilogram live or carcass weight) to bone-free meat weights and add average carbon costs per kilogram for processing, packing, and transport to retail distribution centres, using data from Clune et al. (2017). This approach assumes that the entire carbon emissions of pork and beef should be assigned to meat, and not to other products such as leather or manure, which is appropriate if one assumes that these products would not be used if beef were not being produced. This assumption is debated in the literature (e.g., Vergé et al. 2016), however, given the available data it allows us to generate the most comparable estimates across the animals considered. As a check on the quality of the point estimates we used (i.e, to make sure they were not outliers), we compared our calculated estimates to the range of carbon estimates for beef, pork, and poultry in Clune et al's. (2017) systematic review of life-cycle assessments for a broad range of fresh foods. The most recent Canadian estimates tend to fall in the mid-to-low end of carbon emissions estimates in Clune et al.'s dataset. As earlier, we assume a mix of 50% beef and 50% pork for mammals when calculating emissions based on the reported harvest.

In estimating the dollar value of fish produced in the ISR, we used the retail cost of frozen fish fillets because we felt this was the only reasonably comparable product in the food cost dataset. However, in estimating the equivalent carbon savings we are able to be somewhat more specific. The species that constitute the majority of the Inuvialuit fish harvest are broad whitefish, inconnu, char, and lake trout. Based on the rough proportions of these fish in the 2018 harvest, we take a mix of 70% common market whitefish (cod, pollock, haddock) and 30% salmon/trout (which have very comparable carbon emissions estimates for farmed varieties) for the purpose of estimating carbon emissions. We draw median estimates for each of these groups of fish from Clune et al.'s literature review.

Finally, stores in the Inuvialuit region are exceptionally far away from major distribution centres. Food may travel to the Inuvialuit region through several different routes and modes of transport, including road, barge, and air freight. Carbon emissions of these different modes of transport depend on a wide range of conditions, including the size of the vehicles, engine type, river/sea conditions (in the case of barges), and so on. Given these variations, to approach this problem we adopt a simple approach based on high- and low-ranges of carbon emissions estimates for weight and distance shipped for each mode of transport, derived from the 2014 IPCC report on transport (Table 11). We chose bellyhold cargo for air freight as air freight in the ISR is generally shipped in combined passenger/cargo planes. The estimates in Table 11 are for direct carbon emissions only (e.g., fuel burned), not indirect emissions (e.g., produced in vehicle manufacturing).

Table 10. CO_2-equivalent emission factors (kg CO_2 equivalents per kg boneless meat) for beef, pork, poultry and fish. LW = live weight, CW = carcass weight.

	Adj. Est.	Original Est.	Estimate description	Source
Beef	20.69	9.68 kg CO_2e/kg LW	Western Canada, 2011	Vergé et al. 2018
Pork	4.68	2.33 kg CO_2e/kg CW	Western Canada, 2011	Mackenzie et al. 2015
Chicken	2.69	1.06 kg CO_2e/kg LW	Western Canada, 2006	Vergé et al. 2009
Cod, pollock, haddock (median)	3.40	3.40 kg CO_2e/kg product	Barents Sea line-caught cod	Sund 2009

Salmon, trout (median)	3.47	2.10 kg CO_2e/kg LW	Canada, farmed salmon	Pelletier and Tyedmers 2007

Table 11. Approximate direct carbon emissions ranges for different modes of transport, in grams CO_2/tonne·km, from Sims et al. (2014: Figure 8.6).

Mode of transport	Low	High
Diesel freight train	25	60
Large heavy-duty road vehicle	70	190
Barge	25	60
Short-haul bellyhold in passenger aircraft	800	2000

Table 12. Estimated direct carbon emissions (in kg) per kilogram shipped to each community in the ISR, for six scenarios (Barge, food mail, rail, and high/low emissions for each).

Community	Barge (low)	Barge (high)	Food mail (low)	Food mail (high)	Rail (low)	Rail (high)
Aklavik	0.12	0.31	0.27	0.71	0.08	0.18
Inuvik	0.11	0.30	0.22	0.60	0.07	0.17
Paulatuk	0.13	0.34	0.54	1.40	0.09	0.22
Sachs Harbour	0.13	0.33	0.63	1.63	0.09	0.21
Tuktoyaktuk	0.12	0.31	0.23	0.63	0.08	0.19
Ulukhaktok	0.13	0.34	0.76	1.95	0.09	0.22

We consider two scenarios for food shipping to the region. The first scenario, “barge,” is a lower-carbon scenario that involves food being shipped by truck from Edmonton to Hay River and then by barge to each of the ISR communities (except Aklavik, which is reached by ice road from Inuvik). We choose this scenario based on a 2010 report on transport in northern Canada, which indicated that although there is a rail line to Hay River, rail shipping is primarily used for fuel, while dry cargo is shipped to Hay River by truck (PROLOG Canada Inc. and EBA Engineering Consultants Ltd. 2010). The second scenario, “food mail,” is a higher-carbon scenario based on the shipping scenario for the Food Mail program described by PROLOG Canada Inc. and EBA Engineering Consultants Ltd. (2010). This involves food being shipped by truck from Edmonton to Inuvik and then by air or road (for Tuktoyaktuk) to the other communities. This mode of transport increases the cost of transport considerably for communities with no or limited road access (Aklavik, Paulatuk, Sachs Harbour, and Ulukhaktok). Finally, the “rail” scenario in Table 12 is based on rail freight from Edmonton to Hay River followed by barge to each of the communities (and a short distance by road for Aklavik). We use this scenario later to estimate carbon emissions of gasoline used in harvesting.

Table 12 shows high and low direct carbon emissions estimates for each scenario using the per kilometre emissions estimates from Table 11. We approximated the distances travelled to each community using Google Maps (using straight-line distance from Inuvik for air travel) and other sources (e.g., PROLOG Canada Inc. and EBA Engineering Consultants Ltd. 2010). We consider only one-way costs of transport to the communities, assuming that return trips would occur anyway and/or should be charged to other activities. The approximate distances used to calculate these estimates are provided as a supplementary file (S4). The estimates range from a low of 0.11 kg CO_2/kg for the low range “barge” scenario estimate (to Inuvik) to as high as 1.95 kg CO_2/kg for the high range “food mail” estimate to Ulukhaktok.

To estimate the carbon emitted through the production and transport of retail food substitutes to the ISR, we then simply multiply the harvest estimates for each food type for each village by the carbon emission factors added to the community-specific transport emissions. The results are summarized in Table 13. The high-emissions “food mail” scenario is currently the shipping route for highly perishable goods to the ISR and thus these are the most relevant estimates. A more detailed breakdown of the results of each scenario for each community and by food group are provided in a supplementary file (S5).

Our analysis suggests that a quantity of food equivalent to the harvests reported in the 2018 IHS would produce over 1,000 tonnes of greenhouse gases per year, regardless of the mode of transport. The mean carbon emissions estimates for each transport scenario correspond to 8.5–9.5 kg CO_2-equivalent emissions avoided per kilogram of country food, or between 378–420 kg CO_2-equivalent per Inuvialuit beneficiary in the ISR (gross; we consider carbon inputs to the traditional economy in a subsequent section). For comparison, a one-way economy class flight from Vancouver to Toronto produces 370 kg of carbon emissions (https://www.carbonfootprint.com/calculator.aspx). Thus, the gross carbon savings of the reported harvest is equivalent to more than 1,400 return flights from Vancouver to Toronto. Once again, this is a low estimate which focuses only on the reported harvest; the true harvest could be more than twice the reported amount.

Our approach here has several limitations, many of which we have already highlighted. For instance, we have used general estimates of carbon emissions in transport rather than values specific to the vehicles, loads, and conditions involved in the transport of goods to the ISR. Our analysis also does not include the impacts of wholesale or retail trade sectors. The main change in emissions in this sector that would be associated with greater importation of meat products is the need for expanded frozen storage capacity and electricity to power it. We also do not account for the energy used in freezing meat transported to the ISR.

Finally, it should be noted that current emissions from shipping may also not be a good indicator of future emissions. For instance, low water levels on the Mackenzie River (see CBC 2014) may also compromise the river freight route and force an increased reliance on subsidized air freight or other, longer shipping routes for non-perishable foods that are currently delivered using the Mackenzie barge route. This means that the relative dollar and carbon savings from locally-harvested food may increase due to the impacts of climate change.

Table 13: Estimates of total CO_2-equivalent emissions (in metric tons) generated by production and transport of an amount of retail food equivalent to the harvest reported in the 2018 IHS, with 95% confidence interval for error in harvest measurement.

Scenario	Estimate	Conf. Low	Conf. High
Barge - Low	1047	1038	1055

Barge - High	1071	1062	1079
Foodmail - Low	1082	1073	1090
Foodmail - High	1162	1153	1171

Estimate of production costs

The final step in our measurement of the Inuvialuit Traditional Economy is to estimate non-labour inputs and their associated carbon emissions. Although there are numerous challenges to the estimation of inputs to the Traditional Economy, which we detail below, there are a few studies that have attempted to quantify inputs to traditional harvesting activities in the last two decades. We begin by summarizing their findings.

Chabot (2004), using interview data from 37 Inuit households in Nunavik, estimated that 15% of household budgets was spent on food production (on average $5,646 spent and 1624 kg of food produced per household). However, Chabot provides little detail on the methods used to obtain these estimates. More recently, a study conducted in Paulatuk in 2012 estimated that households with full-time wage employment spent $7,923 on harvesting equipment and supplies, while households with part-time or no employment spent $5,163 (IRC 2012). These estimates were based on self-report data in a household survey and did not include large equipment purchases. Hoover et al. (2013) used a more sophisticated methodology to estimate the costs of beluga and narwhal harvests for Nunavut communities on the Hudson's Bay. They found that the average return of beluga harvests was actually negative (i.e., it cost more than replacement foods). However, in our view their approach greatly overestimates hunting costs because they assigned the entire costs of boats and guns to whale hunts, which ignores that these items are used for a wide range of harvesting activities.

In approaching the question of harvest inputs for the ISR on a regional level, we are faced with considerable data gaps. Data on inputs to the traditional economy are more difficult to collect than harvest reports, partly because they may be difficult to remember and partly because many items circulate through non-monetary exchange. For instance, replacement parts from old snow machines may be exchanged freely among hunters (Collings 2011), and Inuit seamstresses may sew winter clothing without cost to family members who share food with them. Costs are thus distributed across social networks: those who paid for supplies or equipment may not be in the same household as the hunter who uses them.

Second, contemporary harvesting relies on a vast array of equipment, supplies, and local infrastructure; including snowmobiles and boats, fish hooks and bullets, knives, rope, and ice-drills, camp stoves, jerry cans, CB radios, locally-sewn tents, cabins and workshops built by hunters, and rubber boots and parkas, to list only a small portion of the kit required for intensive harvesting. Some of these items may be used for years, even decades, and thus it is not only difficult to obtain data from harvesters on expenditures on this wide array of items, but also necessary to get an idea of the lifetime of these objects. Sales data for hunting-related items in local stores would be one way to get a glimpse of expenditures on hunting gear at the community-level. However, although we have access to some estimates of equipment costs from Inuvik, we do not have extensive data on sales of hunting equipment.

Further, given the multiple kinds of value that land-based activities provide in Inuvialuit communities, the dollar and carbon cost of the equipment required for these activities should in principle not be allocated to harvest production alone. Many of these items should rather be considered essentials for full participation in local life and for wellbeing in ISR communities. Travelling to hunting and fishing camps, for instance, is one of few recreational activities available in small remote communities. Not having access to harvesting gear—which is already a problem for many Inuit (Natcher et al. 2016; Ready 2016; Ready and Collings 2021)—should not be construed as a "dollar or carbon savings" but is rather a serious problem for Inuit welfare that will incur other kinds of costs (e.g., for healthcare).

Consequently, in our view, not all of the costs and emissions associated with harvesting gear and equipment should be allocated to food production. A more appropriate approach might be to assign to food production only the increased costs/emissions resulting from intensive harvesting compared to a hypothetical counterfactual where harvest equipment was only used for "recreational" or "cultural" purposes. In reality, however, land-based activities cannot be divided into "recreational," "cultural" or "productive" categories (Collings et al. 1995); indeed, part of the contribution of land-based activities to Inuit cultural identity and mental health is because the activities are economically productive (Collings 2014). We do not know what level of harvest participation is needed to maintain the documented health and wellness benefits of land-based activities, other than to say that many Inuit already consider participation levels to be too low.

With all these empirical and theoretical difficulties in mind, it is clear why past studies (e.g., Usher 2002) have not attempted to quantify inputs to the ITE on a regional scale. Nevertheless, we think it is important to provide some impression of the scope of expenses incurred by harvesters, as these costs are already burdensome for many Inuvialuit households and carbon pricing policy will increase these costs. Given the data limitations, we focus on two major kinds of expenses that harvesters incur: gasoline used in harvesting trips and vehicle purchases. Gasoline and vehicle production are also the main sources of carbon-emissions in the traditional economy.

We begin with estimating the gasoline used in harvest production. To do this, we use data on 132 hunts from the Tooniktoyok (meaning "extreme determination") study conducted by Angus Naylor with 10 hunters in Ulukhaktok in 2013. We begin with some summary statistics from this dataset that describe the gasoline inputs and other trip costs (e.g., ammunition, food, oil, naphtha; exclusive of major equipment costs) for this set of hunts (Table 14). While this data is highly informative, it should be kept in mind that this is a relatively small sample of hunters and harvest trips, and consequently does not capture the entire range of harvest conditions encountered by Ulukhaktokmiut and may not be representative of broader- or longer-term trends. Nevertheless, it is the best available fine-grained data on harvesting in the ISR.

Table 14 presents the gasoline volume and total trip costs for the trips in the Tooniktoyok dataset, broken down by season (winter/summer, essentially referring to snow-covered versus snow-free season) and by mode of transport. Across all hunts, the median total cost of a trip was $168.44. The median amount of gasoline consumed was 36.37 litres. This amount corresponds to $67.34 at the price of approximately $1.85/l at the time of the study. For hunts where data on both gasoline and total expenditures were available, an average of 49% of the cost of harvest trips (47% in winter and 52% in summer) was gasoline. Winter hunts are on average more expensive and use more fuel than summer hunts in the dataset. ATV hunts use the least fuel per trip (probably because they tend to be used for shorter trips), while boat trips use the most.

An important aspect of the Tooniktoyok data is that it includes information on unsuccessful hunts. Roughly 20% of trips recorded in the Tooniktoyok dataset were unsuccessful (21% in winter and 17% in summer), though according to Naylor, it is that possible unsuccessful hunts were less likely to be reported in the data, so unsuccessful trips may actually be somewhat more frequent than suggested by the data. The information on unsuccessful trips is extremely important in estimating production costs, because the IHS data do not include information on unsuccessful harvest trips. Any attempt to calculate harvest costs strictly from the reported IHS data would miss the expenses incurred for unsuccessful trips.

Table 14: Summary of harvest trip expenditures by harvesters in the Tooniktoyok study (Ulukhaktok, 2013).

	Winter	Summer	Snowmobile	ATV	Boat	**All hunts**
Gasoline volume (l)						
Min	2.27	1.45	2.27	1.45	7.96	**1.45**
Median	43.64	19.09	36.37	22.73	45.46	**36.37**
Mean	54.56	36.13	47.24	22.67	65.22	**47.12**
Max	227.30	250.03	227.3	68.19	190.94	**250.03**
Sample size	71	48	78	22	18	**119**
Total costs						
Min	6.31	3.37	6.31	3.37	41.05	**3.37**
Median	248.66	112.09	275.00	65.65	144.17	**168.44**
Mean	284.20	134.62	278.43	105.57	237.16	**238.87**
Max	1080.00	356.27	1080.00	356.27	776.68	**1080.00**
Sample size	46	20	41	12	13	**66**

Usher's edible weight estimates appear to have been used in the Tooniktoyok data, and so the edible weight data should be highly comparable to the data used in this report. However, a difficulty with the Tooniktoyok data is that while harvesters generally reported their individual hunting expenses, harvests were often reported for groups of harvesters (e.g., if one caribou was caught). Consequently, to avoid overestimating the returns from harvesting when using this data, we take the estimates for individual harvests where they were provided, and where they were not, if it was a snowmobile or boat trip, we divide the harvest by the number of participants on the trip. This is a highly conservative approach that is equivalent to assuming that each participant had their own machine (although two or more people can often ride on a snowmobile, and people may also ride in sleds behind machines). In contrast, for boats we include the total harvest, which assumes that only one boat (with multiple people in it) was involved in the reported catch.

After this adjustment, we ran a Bayesian regression model of the relationship between fuel consumption and edible weight returns in the Tooniktoyok data. The model includes parameters that estimate the probability of unsuccessful trips and the fuel consumption of those trips. We then used this model to estimate not only the fuel consumption represented by edible weight represented in the IHS data, but also the likely number of unobserved unsuccessful trips and their fuel consumption that are not represented in the data. We note that we used the mean of the simulated harvests after deheaping and imputation as the edible weight inputs to our model, and thus the results below do not take the additional error from those procedures into account.

The key results of this model, including conversion of the estimates to costs and carbon emissions, are summarized in Table 15. In total, our model estimates that 127,844 litres of gasoline would have been used in the harvesting of the edible weights reported in the 2018 IHS. It further estimates an associated 819 unsuccessful trips, representing a total of 37,582 litres gasoline. Thus, our total fuel consumption estimate for the harvest reported in the 2018 IHS is 165,436 litres. This corresponds to an average of 51.6 litres per trip, or roughly 1.3 litres per edible kilogram harvested.

We have limited historical information on gas prices, so we used a cost of $1.76 a litre as an approximation for the cost of fuel in 2018, based on the prices reported in a CBC news report which suggested relatively limited differences in fuel costs between communities at that time (CBC 2018). This translates to a total of $292,132 in gasoline costs for the reported harvest, or roughly $2.38 per kilogram. Obviously, these costs are well below the replacement cost of market foods ($25.93/kg); even if gasoline represents only roughly 50% of the cost of harvesting trips, as suggested by the Tooniktoyok data.

In terms of carbon emissions, we again calculated high and low emissions scenarios for shipping of gasoline to the ISR via rail to Hay River followed by barge to each community. We converted kilograms to litres using a density of 0.749, and then added emissions per litre shipping to the carbon emissions produced from burning a litre of gasoline (using the EPA (2018) estimate of 2.319kg/l). We used the average of each of the shipping scenarios across the communities as a single estimate, as the rail shipping scenario generated limited differences in shipping emissions between communities. The results suggest that the carbon emissions associated with the harvest production reported in the IHS could range from 395 to 502 tonnes (corresponding to 3.2–4.1 kg carbon emissions per kilogram food produced). Our previous estimate for market food substitutes was 8.5–9.5 kg per kilogram food.

We next discuss the dollar and carbon cost of vehicles used in harvesting. To do this, we use data on the price of major equipment (snowmobiles, boats, and ATVs) obtained from the Inuvialuit Harvesters Assistance Program (IHAP) in Inuvik (Table 17). IHAP provides grants to harvesters to assist in the purchase of harvesting equipment. Based on the lowest estimates in these data, the cost of a snowmobile and sled, a small boat with outboard motor, rifle, and tent would total $27,793. This of course does not include the cost of myriad smaller items such as camp stoves, sleeping bags and camping mattresses, ice drills, fish hooks, etc.

Table 15. Key results from Bayesian regression model of fuel consumed by edible weight harvested in the Tooniktoyok data, with fuel consumption predictions for the total harvest reported in the 2018 IHS.

	Mean	Std. dev.	5.5% Int.	94.5% Int.
Estimate unobserved fraction	0.25	0.04	0.19	0.32
Total fuel observed hunts (l)	127,843.77	15,581.07	105,835.81	154,932.60
Unsuccessful trips	818.68	170.77	567.00	1,107.00

Total fuel unsuccessful trips (l)	37,582.26	13,888.09	20,910.17	62,129.28
Total fuel estimate (l)	165,426.03	20,827.70	1365,43.03	201,030.96
Fuel cost ($)	292,132.97	37,889.17	239,072.08	358,078.79
Carbon emissions - low (tonnes)	395.32	51.27	323.52	484.56
Carbon emissions - high (tonnes)	409.60	53.12	335.21	502.07

Table 17. IHAP price estimates for hunting gear, Inuvik 2021

Item	Price estimates ($)
Snowmobile	9,899.00 – 18,215.40
ATV	10,400.00 – 20,450.85
Boat	14,336.02 – 66,045.00
Outboard motor	10,456.74 – 13,658.73
Rifle	1,479.44
Sled	699.00 – 4,882.50
Stove	1,393.95 – 6,605.64
Generator	1,605.45 – 2,152.49
Tent	1,350.00 – 2,268.75
Chainsaw	524.99 – 893.54

Approximate greenhouse gas emissions from the production of vehicles used in harvesting were calculated using the Economic Input-Output Life Cycle Assessment tool from Carnegie Mellon University (http://www.eiolca.net/). To use the tool, we converted the rough price ranges of snowmobiles and ATVs ($10,000 – $20,000) and boats ($15,000 – $66,000) to 2002 US dollars and ran these values through the "2002 purchaser" model, which allows an estimation of the costs of production of an item of a given purchase price in a certain sector to the point of purchase. This generated estimates of 3.22–14.0 tonnes of carbon emissions per boat (using the "Boat building" model) and 2.30–4.53 tonnes of carbon emissions for snowmobiles and ATVs (for which we used the model for "All other transportation manufacturing"). The low estimates are probably most appropriate for our case, particularly for boats. We do not adjust for additional shipping-related emissions here, as non-air freight shipping would contribute a negligible amount relative to the scale of the vehicle production emissions.

Unfortunately, in converting these per-vehicle estimates to yearly costs and emissions amounts, we are faced with a serious lack of data on two fronts: first, regarding the number of vehicles in use (or per harvester) in the ISR and second, on the average lifetime of these vehicles. Wenzel (1991) estimated an average 2.7 year lifespan for snowmobiles and 6.9 for boats in Clyde River, Nunavut in 1985. However, we think these estimates are too low, and suggest that 5 years for snowmobiles and 10 years for boats (and ATVs) may be more appropriate today. In Wenzel's data, there was roughly one snowmobile for every two adult males in Clyde River and one boat for every three.

If we take the approximate ownership rates from Wenzel and apply them to the 1039 HTC members in the ISR in 2018, this would total 520 snowmobiles and 346 boats. We think one in three is also a reasonable starting estimate for ATV ownership. At the replacement rates above, this would translate to roughly 139 new snowmobiles/ATVs and 35 boats required in the ISR region each year, corresponding to a total of roughly $1.92 million in major equipment purchases per year, and related emissions of 432 tonnes CO_2-equivalent for low-end equipment.

Given the costs and carbon emissions of gasoline inputs previously calculated, this would lead to a total of approximately $2.21 million spent on vehicles and gasoline, still well below the retail substitution costs of $3.18 million. In terms of carbon emissions, if we include the entire cost of vehicle production estimated above, the total yearly emissions could be in the range of 827–924 tonnes CO_2-equivalent, close to but still lower than the total estimates of market food substitutes (1082–1171 tonnes for food mail). However, since the "true" harvests are undoubtedly higher than our estimates, the proportion of carbon emissions represented by vehicle production may actually be considerably lower, meaning a relatively higher carbon savings. Again, our estimates of vehicle ownership rates and lifespans should at best be considered informed "guesstimates." However, it should be remembered that even if the carbon emissions of traditional and market foods were equal, the traditional economy provides many other kinds of social and economic value that are not generated by imported food. Nevertheless, it seems clear that increasing the longevity and fuel efficiency of vehicles could be an extremely effective way to reduce both the cost of and carbon emissions associated with harvesting activities, and could further increase their cost and carbon-efficiency relative to imported market foods.

How will carbon pricing impact the traditional economy?

In this section, we discuss how an increase in the cost of harvesting due to carbon pricing might impact the Inuvialuit Traditional Economy.

Impact of fossil fuel prices on harvesting activities

There are several ways that the relationship between fossil fuel prices and harvesting activities could potentially be examined. The most straightforward approach would be to directly examine the relationship between harvest levels (or better, gas purchases for harvest purposes) in Inuvialuit communities and gas prices. In the absence of local historical data on gas prices, a national index of gas prices might be a sufficient proxy, as gas prices have undergone considerable fluctuations in recent years that would presumably be reflected in gas prices in the Inuvialuit region. In the absence of data on gas usage, a correlation between sales of food at local stores and gas prices might be sought for. The relationship between past gasoline prices and harvest levels could then be used to generate projections based on future costs of fossil fuels. Importantly, however, given the complexity of the system it is not clear if all important confounds could be identified and controlled for, meaning that such models may not reveal the effect of interest. For instance, unmeasured year-to-year variation in animal abundance might prompt different gas usage patterns, or there could be time-lags between changes in fuel prices and changes in store food purchasing due to consumption of country food kept in storage.

It should be further noted that the assumption that the observed relationship between fossil fuel consumption and harvesting in past years will hold in the future may be tenuous. According to Usher and colleagues (2003: 188): "Measuring the sensitivity of subsistence-based economies to change is problematic, however, precisely because subsistence is a flexible and resilient system. Its participants can and do adapt to change, whether adverse or beneficial." Traditional economies are complex, dynamic systems, and relationships between parts of the system (e.g., harvest and gas consumption) may change through time—indeed, they clearly have done so over the past century.

Beyond these theoretical limitations, the data necessary to tackle such an analysis is not readily available. Initially, we hoped to conduct a preliminary attempt to validate the type of approach described above using the 1988–1997 IHS data. However, due to technical issues this data was not available in time for the preparation of this report. More systematic collection of data on fuel purchases for harvesting and local fuel prices could potentially help address this problem in the future.

In the absence of the necessary data for a quantitative model, we instead summarize the results of qualitative research on the role of gasoline prices in Inuit harvesting, which has suggested that current price levels are already a substantial barrier to harvesting (Usher et al. 2003; Lambden et al. 2006; Ready 2016; Ready and Collings 2020, see also CBC 2018). Natcher et al. (2016) found that for Inuit hunters in Nunavik, costs were the primary barrier to harvesting activities, and in Nunatsiavut, costs were the second most commonly cited barrier, after poor health. Ready (2016) found that more than 50% of households in Kangiqsujuaq felt that the cost of harvesting equipment and supplies were a barrier to harvesting as much as they wished, and Ready and Collings (2021) reported that the cost of living was an issue that Kangiqsujuarmiut considered among the biggest problems in their community. Many harvesters in the latter study specifically mentioned the cost of hunting as a problem. In a survey on food affordability that included the Inuvialuit region, Lambden et al. (2006) found that, depending on their age group, 37.7–46% of Inuit women reported that hunting was unaffordable, and 30.1–40.2% reported that fishing was unaffordable. These findings indicate that many Inuit are already reducing their engagement—or are entirely prevented from engaging—in harvesting due its cost. Clearly, the ability of Inuvialuit to absorb future increases in the cost of harvesting is limited. Further increases in the cost of harvest may force more Inuvialuit out of participation in harvesting and others to reduce their harvesting activities, resulting in greater dependence on imported market foods which, as described here.

Finally, it should be acknowledged that given recent global market fluctuations, the current price of gasoline (including carbon taxes) does not exceed previous price extremes in the region (e.g., CBC 2020). For example, current gasoline prices in Ulukhaktok are $1.78 a litre (Government of the Northwest Territories 2020), but during the Tooniktoyok study in 2013—a period of exceptionally high oil prices—the price per litre of gasoline in the community was $1.85. If oil prices remain at the current low levels, levels of taxation on gasoline planned to 2022 (Table 18) could remain within previously experienced price levels. However, as described above, the "status quo" in the cost of harvesting should not be considered acceptable, as harvesting activities are already unaffordable for many Inuvialuit. And, recovery in the market and/or further increases in tax levels beyond 2022 (which the federal government is currently planning) could easily push gas prices beyond historic highs. This point serves to highlight that the effect of carbon pricing on Inuvialuit will also depend on global market prices. Policy intended to protect the traditional economy should bear in mind not only the levels of carbon tax, but the potential impact of the combined effect of market prices and taxation.

Table 18. Proposed NWT Carbon Tax Rates, by Fuel Type (cents/litre) (Government of the Northwest Territories 2018).

	Jul-19	Jul-20	Jul-21	Jul-22
Gasoline	4.7	7.0	9.4	11.7
Diesel and heating fuel	5.5	8.2	10.9	13.7
Propane	3.1	4.6	6.2	7.7
Natural gas	3.8	5.8	7.7	9.6
Naphtha	5.1	7.7	10.2	12.8

Other costs to Inuvialuit welfare

Our analysis has focused on the economic value of food produced in the Inuvialuit Traditional Economy, to the exclusion of other important economic contributions which are extremely difficult to quantify. Here, based on our earlier literature review, we briefly summarize several other kinds of costs that decreases in harvesting might incur for Inuvialuit, without attempting to quantify them.

The first is lowered diet quality, which could result in reductions in Inuvialuit health and increases in the need for health services. Although our analysis has focused on the substitution value of comparable meat products, the reality is that many Inuvialuit would not be able to afford these meat products and would likely rely more on less nutrient-dense foods instead (Kenny et al. 2018b). Thus, any reduction in the availability of traditional foods is likely to have serious consequences for Inuit nutrition, which may lead to an even more dramatic need for improved subsidies for imported healthy foods and increased health costs relating to problems such as cardiovascular disease, diabetes, and tooth decay.

Reduced harvesting and less time spent engaging in "on-the-land" activities may also lead to poorer mental health and lowered life satisfaction among Inuvialuit. If participation in the ITE were significantly decreased, investments in on-the-land healing and other wellness programs would have to be substantially increased or Inuvialuit would have to increase their reliance on less effective and less culturally appropriate social services.

Decreased harvesting could reduce the transmission of knowledge (hunting, on-the-land skills, food prep, textiles, tools, etc) to future generations (Pearce et al. 2010). Loss of this knowledge would result in greater economic dependence of Inuvialuit on global markets and likely on the Canadian government for subsidies and support. Similarly, weakening of social networks that are produced and maintained through sharing and other activities in the traditional economy may also disrupt local social capital, eroding Inuvialuit sense of community identity, and reduce trust within communities. This could reduce the capacity of communities to respond to other new and ongoing stressors (e.g., climate change).

The Inuvialuit Traditional Economy is also not just an economic system, but a social and cultural system. For Inuvialuit, hunting and fishing are not simply a kind of "job," but rather a way of life. The persistence of the ITE through the radical changes of the past century reflects the high value that Inuvialuit place on this way of life. As argued by Brown and Burch (1992: 224), changes that impact access to wildlife resources are likely to have negative (and difficult to predict) cultural impacts for Indigenous subsistence hunters, for whom these resources "are not only inputs to physical well-being, but also symbols around which cultural identity and cohesion revolve." Economic valuation of the loss of this cultural heritage is both impossible and culturally inappropriate (Brown and Burch 1992).

Finally, the ITE has an existence value even to non-Inuvialuit (Brown and Burch 1992). Inuvialuit culture, which includes the traditional economy, is perceived as interesting and valuable to people around the world. Inuit art, which is often inspired by and even uses raw materials from hunting and trapping, has played an extremely important role in how Canadian culture is represented internationally (Stuart Pupchek 2009). The vitality and persistence of the Inuvialuit Traditional Economy is thus also linked to Canada's international reputation, as well as to the tourism and creative sectors.

In summary, by worsening the quality of life, mental health and cultural continuity of Inuvialuit families, harm to the traditional economy could substantially increase the costs Canada pays to replace these locally-provided goods and services.

A safer path to greenhouse gas reduction in the ISR

Summary of findings

The Inuvialuit Traditional Economy is an economic system based on the harvesting, sharing, and use of wildlife. It has persisted in the ISR despite the disruptive impact of settlement and integration into the cash economy over the last century. The traditional economy distributes resources and coordinates action through a system of exchange, reciprocity, familial bonds and accrued social capital. It improves Inuvialuit food security and nutrition and provides access to resources for those less engaged with the cash economy. Participation in the Traditional Economy builds networks of trust and social capital, and is a foundation for Inuit cultural identity and wellbeing.

Bringing food, energy, skilled labour and goods to the remote Arctic is expensive. This puts the region at a major competitive disadvantage in the global economy, an issue which is reflected in the limited economic opportunities and high rates of poverty in the Inuvialuit region. Our analysis indicates that 122,677 kg of food were represented in the 2018 Inuvialuit Harvest Study data. The retail substitution cost of this amount of meat in the ISR is over 3.18 million dollars. If commercially farmed meats shipped by food mail were substituted for this quantity of food, they would produce approximately 1082–1171 tonnes of CO_2-equivalent emissions. The total amount of food produced in the ISR in 2018 is likely considerably higher than our estimates, however, possibly more than twice as much. Gasoline consumed in the production of local harvests results in carbon emissions that are less than half of those of an equivalent amount of market foods. Due to a lack of data, we could not calculate a precise estimate for the carbon emissions related to the production of vehicles used in harvesting. Nevertheless, it is clear that the ITE dramatically reduces the need for food to be inefficiently transported from southern markets.

Our ability to analyze inputs to the traditional economy, and its sensitivity to fossil fuel prices, is limited due to a lack of data. However, the Inuvialuit Traditional Economy is heavily dependent on gasoline, a dependence that cannot be easily eliminated with currently available technology. Inuvialuit already experience an extremely high cost of living and high rates of poverty compared to other Canadians; and research with Inuit throughout Canada has already established that costs are already a major barrier to participation in harvesting. By increasing the cost of traditional HFT, carbon pricing potentially threatens harvest production in the ISR and the numerous kinds of value it produces. Substantial increases to the cost of participating in harvesting could erode the social capital produced by the Traditional Economy, preclude the documented health benefits of time spent on the land for many Inuvialuit, and interrupt the transmission of HFT skills to future generations. Consequently, carbon pricing needs to be implemented carefully in the ISR.

Limitations of this study

The major limitation of this study is the absence of fine-grained data on many aspects of the Traditional Economy, particularly regarding inputs including labour, fossil fuels, purchases of vehicles, and other imported supplies. There are considerable limitations to the Inuvialuit Harvest Study data, including potential biases in the sample of harvesters and missing data for some months, which led us to focus on obtaining a minimum estimate for the regional harvest, due to the uncertainty that would be inherent in any attempt to extrapolate from the IHS data. Though we have done our best with the available data, the results of this study should be treated with caution, and in no way should be considered highly precise estimates. In particular, past research has emphasized high levels of variation in harvest from year-to-year (due to factors as varied as road closures, winds, research vessels scaring beluga, and unexpected movements of the caribou herd), and so a one-year estimate should not necessarily be considered "typical."

Our analysis also does not account for future changes in the environment (e.g., due to climate change) that may impact HFT activities. If weather conditions or animal distributions change, hunters will need to adapt. Doing so requires them to gather information and learn about new conditions, and may increase the distances travelled and therefore increase fuel needs. Ongoing technological improvements (e.g., in electricity generation in communities and in the suitability of electric vehicles for use in the Arctic) may also change the emissions involved in various activities (e.g., shipping) in the near future.

Finally, we have also not attempted to quantify many of the more indirect or intangible ways that the Inuvialuit Traditional Economy produces value and reduces other kinds of costs, for instance, in promoting mental health. It is essential to re-emphasize that calculating the value of the tangible products of the Traditional Economy (i.e., food), as we have done, absolutely fails to capture the meaning and value of these activities for Inuvialuit.

Recommendations

Our analysis suggests that the traditional economy produces considerable monetary and non-monetary economic value for Inuvialuit. In particular, the country food produced in the ISR totals millions of dollars in value and avoids the carbon-intensive production and transport of a large amount of commercial foods to this remote region. We emphasize that our analyses should be considered preliminary due to issues relating to data availability, data quality, and an as-yet insufficiently developed theoretical and empirical understanding of how traditional economies reorganize and respond dynamically to change. Nevertheless, it is clear that proceeding with steep and rapid carbon price increases could potentially have severe negative consequences for the economic, social, cultural, mental and physical health of Inuvialuit.

A safer path to greenhouse gas reduction in the ISR—for Canada, the GNWT, and the Inuvialuit—will involve deliberately measuring and studying the traditional economy and planning a path to gradually reduce its gasoline dependence. A first step involves collection of more baseline data. Better incentives for participation in the Inuvialuit Harvest Survey and attempts to assess measurement error in the survey would be helpful in this regard. The sampling strategy of the Inuvialuit Harvest Survey could likely be improved in ways that would both enhance the representativity of the survey and minimize respondent burden (e.g., sampling a smaller number of harvesters more consistently). Data on inputs to the Traditional Economy, including labour, money, and supplies (particularly vehicles) are also needed. While this data collection and study process takes place, we suggest that GNWT and Canada should fully offset the effects of carbon pricing for traditional HFT in the ISR. As carbon price increases are later implemented, monitoring studies should be undertaken to examine their effects on the traditional economy so that negative impacts can be observed—and mitigated—before they become severe. This means that carbon pricing may need to be implemented more slowly in the ISR than in other parts of Canada.

In the longer term, measures to reduce carbon emissions and gasoline dependence in the ISR need to recognize the unique reality of the region. For instance, given currently available technology, green energy sources cannot replace fossil fuel-derived power for vehicles in the ISR. These constraints are a result of the unique geography, climate, and history of the ISR, and mean that reliance on fossil fuels remains a necessity for Inuvialuit. Instead of being penalized for this reliance, harvesters should be incentivized to adopt equipment and behaviors that decrease their reliance on them. Given the high carbon emissions involved in vehicle production, improving the longevity of HFT vehicles may be one of the most effective ways to reduce carbon emissions relating to food-consumption and production in the ISR. Decreasing the fuel consumption of HFT vehicles is another realistic avenue for reducing carbon emissions without damaging the traditional economy. For instance, fuel-efficient four-stroke snowmobiles might be subsidized relative to less-efficient two-stroke machines.

We further highlight two features of the Inuvialuit Economy that are particularly important to account for in the implementation of carbon pricing policy in the ISR. First is the high year-to-year variability in subsistence harvests. Rigid policies based on historical data that impose limits on fossil fuels used for subsistence may constrain hunters from responding adaptively to changes in their environment—for instance, harvesters may need to travel more in certain years to collect information about a changed environment. In our view, maintaining the ability of harvesters to react flexibility and dynamically to their local environment is an important component of protecting harvest production and reducing dependence on imported foods.

The second feature is the unevenness of harvest production across households, combined with the redistribution of foods through sharing. Providing offset payments to households without accounting for differences in harvest production may force high-producing households to absorb disproportionate costs and consequently limit their ability to harvest and share food to other households. Policies should take care to support the needs of different kinds of harvesters in recognition of the fact that harvesting provides benefits that are distributed beyond the household.

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Glossary

GNWT: Government of the Northwest Territories

HFT: Hunting, fishing and trapping

HTC: Hunters' and trappers' committee

IFA: Inuvialuit Final Agreement

IHS: Inuvialuit Harvest Study. Not to be confused with the 2007–2008 Inuit Health Study, often referred to as IHS in the literature, but which we refer to using the full title.

Inuit Nunangat: Inuit homelands in Canada, comprising the Inuvialuit Settlement Region, Nunavut, Nunavik, and Nunatsiavut

IRC: Inuvialuit Regional Council

ISR: Inuvialuit Settlement Region

ITE: Inuvialuit Traditional Economy

List of supplementary files

S1. Edible weight data (comma-separated value file)

S2. Harvest estimates by community (comma-separated value file)

S3. Edible weight estimates by community (comma-separated value file)

S4. Transport emissions to ISR communities (comma-separated value file)

S5. Estimated carbon emissions for different transport scenarios (comma-separated value file)

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