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Inuit Traditional Ecological Knowledge of Anadromous Arctic Char, *iqalukpik (Salvelinus alpinus)* Under Changing Climatic Conditions in the Amundsen Gulf, Western Canadian Arctic

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ABSTRACT. Inuit in the western Canadian Arctic have observed climate change impacts in marine and freshwater environments that have resulted in changes in the abundance, movement ecology, and health of Arctic char, *iqalukpik* (*Salvelinus alpinus*), with implications for their fisheries. This research was co-designed with Inuit to investigate reported changes in anadromous Arctic char in waters near Ulukhaktok, Northwest Territories, Canada. An analysis of semi-structured interviews with 26 Inuit fishers not only documented changes in Arctic char population abundance, spatial movement, appearance, and taste but also changes in access to the fishery. Over the past several decades and becoming pronounced in recent years, fewer fish and specifically fewer medium-sized fish that are preferred by fishers, have been caught using nets near the settlement, with some showing poor body condition, and others appearing to originate from lakes outside of the expected spatial range, earlier in an extended summer coastal fishing season. Inuit have observed changes in individual fish with broader environmental changes that are also disrupting fishing activities: the increasing prevalence of Pacific salmon, warmer air and marine sea surface temperatures, inconsistent sea and lake ice conditions, stronger and more frequent wind and wave activity, fluctuating water levels in rivers, and a seasonal tunicate bloom. Inuit have responded to these changes by altering personal subsistence fishing practices and temporarily halting a small-scale community-based commercial fishery because of observations in stock declines and in order to prioritize the subsistence fishery.

Keywords: adaptation; fisheries; Indigenous; Inuvialuit; subsistence; TEK; Ulukhaktok

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INTRODUCTION

The Arctic is experiencing an unprecedented rate of transformation due to warming temperatures, particularly in its oceans, which support ecosystems and species that are critical for Indigenous people's economy, subsistence, and culture (Falardeau and Bennet, 2019; Landrum and Holland, 2020; Druckenmiller et al. 2022; Rantanen et al. 2022). Aquatic habitats and food webs affected or modified by direct and indirect consequences of climate change will impact access to and patterns, processes, and resilience of various large- and/or small-scale commercial, subsistence, and recreational fisheries, which requires adaptive management responses not only to conserve and protect aquatic species but also the livelihood of people who rely on them (Badjeck, 2010; Moerlein and Carothers, 2012; Brinkman et al., 2016; Hunt et al., 2016; Sharfil et al., 2017; Mueter et al., 2021). Coastal nearshore subsistence fisheries in the Arctic (often shore-based) vital to the well-being of communities have experienced changes including patterns in erosion, weather, temperature, and ice, along with shifts in species range and behaviours (Savo et al., 2016; Savo et al., 2017; Dunmall et al. 2018). These changes have the potential to affect the productivity of fish stocks and their life history characteristics including growth, reproduction, and migration, particularly for anadromous species, which move between freshwater (breeding) and marine (feeding) habitats and must contend with added complexities of the changes exacerbating multiple habitat types to varying extents (Reist et al., 2006; Chaparro-Pedraza and de Roos, 2019; Tamario et al., 2019). Anadromous species support multiple types of fisheries and economies throughout the circumpolar North, including salmonid fishes of the genus *Salvelinus*, which are especially critical for many Indigenous communities in Arctic North America (Armstrong and Morrow, 1980; Johnson, 1980; Reist 2018).

Arctic char, *iqalukpik* (*Salvelinus alpinus*) is the northernmost of all *Salvelinus* species and the only freshwater fish with a circumpolar distribution (Klemetsen et al., 2003). They can occupy numerous aquatic habitats during their lifespan, such as lakes, streams, rivers, and marine environments (Reist et al., 2013). Arctic char can exhibit distinct life histories that include anadromy through undertaking seasonal migrations between freshwater and highly productive marine habitats, and resident (typically landlocked), which remain in freshwater throughout their lifespan (Johnson, 1980; Jonsson and Jonsson, 2001). Since their life history characteristics are highly influenced by environmental conditions, habitat use, and food consumption, they are a strong indicator of environmental change (Reist & Sawatzky, 2010; Chavarie et al., 2019) and variability (Harwood et al., 2013). As the most abundant anadromous salmonid in the Arctic, they are fished by many Inuit communities for subsistence and commercial purposes (Usher, 2002; Sawatzky & Reist, 2010; Government of Nunavut, 2016).

Traditional harvest practices are closely linked to the migrations undertaken by anadromous Arctic char, which move from freshwater habitats in spring during ice-breakup to feed in the ocean during summer and subsequently return to freshwater from late summer to early fall. The majority of Inuit communities are coastal, which provides Inuit the opportunity to more easily harvest anadromous Arctic char, a high quality and nutrient-rich (e.g., long-chain omega-3 polyunsaturated fatty acids) food source, during the open water season (Lemire et al., 2015). Anadromous and resident Arctic char overwintering in freshwater are typically harvested by Inuit in under-ice fisheries. For Inuit, Arctic char represents self-sufficiency in food security and the traditional subsistence lifestyle (Condon et al., 1995; Reist, 2018). Arctic char also play a central role in Inuit food sharing networks and managing social relations (Knopp et al., 2012; Condon & Ogina, 1996). In recent years, Inuit living in the Amundsen and Coronation Gulf areas of the Canadian Arctic have reported fluctuations in anadromous Arctic char population abundance, movement ecology, and the health of some fish, with concerns for fishing and local food security (Falardeau et al., 2022; Harris et al., 2022; McLennan et al., 2022; Lea et al., 2023a).

To date, most studies in the Amundsen and Coronation Gulf areas of the Canadian Arctic have focused on collecting harvest, catch-effort, and biological information of Arctic char from long-term (30 + years in some cases) community-based harvest monitoring programs to reveal, document, and track changes in Arctic char (e.g. Bell and Harwood, 2012; Harwood et al., 2013; Gallagher et al., 2021; Lea et al., 2023b). These ongoing monitoring programs are major sources of quantitative data for fisheries management purposes. Other scientific research has provided information on Arctic char population status (Zhu et al., 2017), movement ecology (Hollins et al., 2022; Smith et al., 2022), morphotypes (Burke et al., 2022), and evidence of early responses to climatic change (Reist et al., 2006; Finstead and Hein, 2012). These studies have helped to advance our understanding of Arctic char and their responses to climate change (e.g., timing of sea ice clearance; Harwood et al., 2013). Another, complementary, way of generating and sharing knowledge about arctic wildlife, including Arctic char, in a changing climate is traditional ecological knowledge (TEK) (referred to in the eastern Canadian Arctic as Inuit Qaujimajatuqangit). TEK refers to a "cumulative body of knowledge, practice, beliefs, and values evolving by adaptive processes and handed down through generations by cultural transmissions, about the relationship of living beings (including humans) with one another and with their environment" (Berkes, 1999). Inuit harvesters who are closely connected to their local surroundings are often the first to detect environmental change because they are exceptionally good at observing extreme events, variations, and unusual patterns, and remembering them through oral history and social memory—TEK can be described as a "long science" (Moller et al., 2004). TEK strives for an understanding of

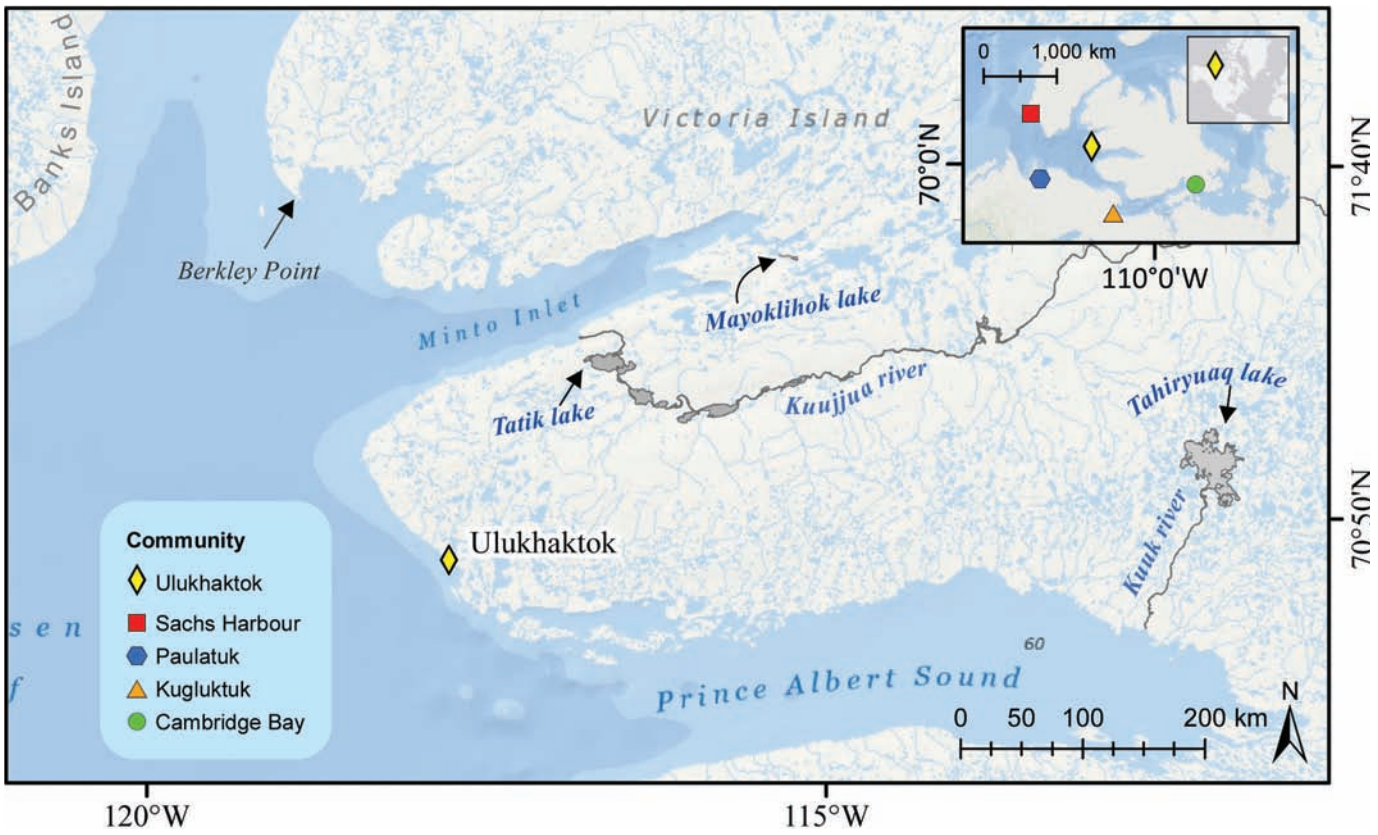

FIG. 1. Key locations related to Arctic char habitat and fishing locations in the Amundsen Gulf, Canadian Arctic (main map). Location of Ulukhaktok relative to other Inuit communities (inset map). Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin©, HERE, Geonames.org, OpenStreetMap, the GIS community and other contributors.

the whole and Inuit draw on past knowledge, lessons, and experiences to interpret observations of wildlife in the context of other environmental processes and forces (Pearce et al., 2015; Pettit-Wade et al., 2020). It is for these reasons that resource managers in the Arctic (e.g., Dubos et al., 2023—Nunavik; Farladeau et al., 2022—Kitikmeot region), and elsewhere (e.g., Butler et al., 2012—Australia) seek to combine science and TEK to monitor customary harvests (Moller et al., 2004). This paper documents Inuit TEK of environmental changes and their effect on anadromous Arctic char and the char fishery in waters near Ulukhaktok (formerly Holman), Northwest Territories, Canada.

Arctic Char Co-management in Ulukhaktok

Ulukhaktok is a coastal Inuit community of approximately 470 people (88% Inuit) located at the mouth of Prince Albert Sound (PAS) on the west coast of Victoria Island in the Inuvialuit Settlement Region (ISR), NWT, Canada (70˚45'42" N, 117˚48'20" W) (NWT Bureau of Statistics, 2019) (Figure 1). Historically, the region was home to the Northern Copper Inuit, who are known for their migratory seasonal hunting and nomadic lifestyle (Condon & Ogina, 1996). Spending time on the land, subsistence activities, country food, and an ethos of food sharing continue to be important in Ulukhaktok (e.g., Pearce et al., 2010)responses to climatic variations, future climate change projections, and non-climate factors that influence people's susceptibility and adaptive capacity. The paper documents and describes exposure sensitivities to climate change experienced in the community of Ulukhaktok, Northwest Territories and the adaptive strategies employed. It is based on collaborative research involving semi-structured interviews, secondary sources of information, and participant observations. In the context of subsistence hunting, changes in temperature, seasonal patterns (for example timing and nature of the spring melt. According to a community survey conducted in 2019, 79% of residents participate in traditional hunting and fishing activities, and 47% of the population consumes the majority of their meat and fish through local harvests (NWT Bureau of Statistics, 2019). For many coastal Inuit communities such as Ulukhaktok, marine resources form the foundation of their traditional diet (Falardeau & Bennett, 2019), where fish such as Arctic char are a species of high importance (Ayles et al., 2007; Olokhaktomiut Community Conservation Plan, 2016).

Anadromous Arctic char in the Ulukhaktok area have been harvested seasonally for subsistence and small-scale commercial purposes during summer and fall months (Lea et al. 2023b). Most of the harvest happens during summer in coastal waters, and then into late-fall/early winter at the lakes used as overwintering habitat. Contemporary harvest surveys (2004–2015) revealed an average of approximately 3500 anadromous Arctic char from multiple

populations were harvested annually for subsistence by Inuit with the majority occurring during summer in a mixed-stock fishery along the coast (Lea et al. 2023b). Winter fisheries for anadromous Arctic char occur mainly in Tatik Lake (Kuujjua River) although other locations such as Mayoklihok Lake are used as well (Fig. 1). Additionally, resident (or landlocked) Arctic char also contribute to subsistence where the large majority of the approximately 200 fish annually harvested are taken from lakes under the ice during spring (Lea et al., 2023b). Regardless of the season, when Inuit harvest Arctic char they will either consume the fish immediately or prepare and store for future consumption (e.g., dried (*piffi*), frozen raw (*quaq*), smoked) or distribute to family members in the community and living elsewhere (Stern & Gaden, 2015); Arctic char play a fundamental role in community sharing networks and social relations (Condon & Ogina, 1996). Arctic char's value has also evolved to hold economic importance after a small–scale community-based commercial fishery began in Ulukhaktok with harvesters selling their catch regionally within the Northwest Territories (Lewis et al., 1989; Fawcett et al., 2018). The community-based commercial fishery started in 2000 with a quota of 100 fish, then in 2001 it went up to 500 fish and was increased to 700 fish in 2016 until the fishery was put on hold in 2020 (Lea et al., 2023a).

The Inuvialuit Settlement Region (ISR) was created in 1984 with the signing of the Inuvialuit Final Agreement (IFA), a land settlement agreement between six Inuit communities and the Canadian Government. The IFA recognizes Inuvialuit exclusive harvesting rights to certain species and their responsibility to co–manage wildlife resources (IFA, 1984; Usher, 2002). Several co-management boards were created under the IFA including the Wildlife Management Advisory Council (NWT), Fisheries Joint Management Committee (FJMC), Inuvialuit Game Council (IGC), and Inuvialuit Hunters and Trappers Committees (HTCs) (IFA, 1984). As early as 1987, Ulukhaktomiut (Inuit from Ulukhaktok) noticed a decline in the size and population abundance of local Arctic char, specifically the Kuujjua River stock (Ayles et al., 2007; Holman Char Working Group, 2004). Due to stock depletion in the early 1990s, the community voluntarily closed Tatik Lake to all fishing between 1993 and 1995 (Holman Char Working Group, 2004; DFO, 2016). In response to this concern, the Department of Fisheries and Oceans (DFO), Fisheries Joint Management Committee (FJMC), and Olokhaktomiut Hunters and Trappers Committee (OHTC) established the Holman (now Ulukhaktok) Char Working Group (HCWG or UCWG) to monitor changes and offer suggestions to resource co-managers. The UCWG is responsible for developing fisheries management measures in consultation with co-managers; providing guidance for researchers on community priorities; allocating harvest quotas and monitoring fish harvests by residents; participating in research design and projects; and reporting all pertinent information back to the DFO, FJMC and Hunters & Trappers Committee (HTC) at the regional level to inform decision-making (Holman Char Working Group, 2004). Co-managers meet annually to discuss community-relevant research needs, provide updates on indicators of stock status of Arctic char from ongoing annual community-based fisheries-dependent monitoring programs (see Gallagher et al., 2021; Lea et al., 2023b), and discuss other information to strategize ways to move forward (Holman Char Working Group, 2004). The UCWG uses an adaptive co-management approach to manage and monitor Arctic char that reflects traditional and scientific knowledge in decision-making.

In 2019, the UCWG requested research to document TEK of anadromous Arctic char under changing climatic conditions and implications for the fishery, to complement existing scientific knowledge, and help guide future monitoring and research directions (e.g., generate new research questions and build new hypotheses, expand our understanding of complex systems, and establish a stronger link between science and community (Moller et al., 2004)). Our objectives were to: (1) document general knowledge of anadromous Arctic char and observed changes; (2) document environmental changes and their perceived effect on anadromous Arctic char and community fisheries; and (3) discuss individual harvester and community-level responses. This study expands upon previous research with Inuit in Ulukhaktok that recorded TEK of Arctic char under changing climatic conditions (Paylor, 1998; Knopp et al., 2017).

METHODS

Research Design

The study was co-designed by the UCWG and OHTC with university (University of Northern British Columbia and University of Manitoba) and DFO researchers following considerations outline by Pearce et al. (2009). Specifically, the researchers met with the UCWG and OHTC in-person in February 2020 to confirm the research questions and plan data collection. The researchers intended to return to Ulukhaktok to conduct interviews between April and August 2020, but in-person activities were not possible given COVID-19 pandemic travel and social distancing restrictions. The researchers continually monitored the COVID-19 travel restrictions and risk assessment with the community, with the OHTC ultimately deciding in January 2021 to proceed with the interviews using a hybrid approach where a local Inuit researcher would conduct the interviews in-person with the support of the university researchers connecting remotely by speaker phone. The researchers worked with the OHTC to hire a local researcher, Susie Memogana, and recruit interviewees that were knowledgeable about Arctic char and their fisheries. Susie had experience working with the researchers on previous projects so rapport was strong, which made communicating during the data collection process easier. A list of potential interviewees was made by the OHTC and

TABLE 1. Demographic characteristics of interviewees in Ulukhaktok.

Age cohort	Gender		Total
	Female	Male	
Young Adult (18–34)	0	0	0
Adult (35–54)	6	1	7
Elder (55–74)	7	9	14
Oldest Elder (75+)	1	2	3
Total	13	13	26

researchers, considering representation across age, gender, and fishing experience, including those previously active in the fishery and those currently active. Study protocols were approved by the Human Research Ethics Board at the University of Northern British Columbia. The research was licensed by the Aurora Research Institute (#16767), which oversees research in the Northwest Territories.

Data Collection and Analysis

Interviews were conducted with 26 participants from 21 households (five interviews were conducted in pairs-married couples) (Table 1). The interviews were conducted between February 16th and March 11th, 2021 at the interviewee's house or at the OHTC office with university researcher(s) on the speaker phone, and some of the interviews were arranged by Susie, but conducted solely by university researchers. For flexibility, interviews were semi-directed conversation-style with open-ended questions, allowing the interviewee to freely speak about topics and concerns important to them (Hay, 2016). A list of topics, themes and questions were used as a reference guide (Huntington, 1998) (Table 2). Interviews were conducted in English and Inuinnaqtun, with Inuinnaqtun responses simultaneously translated into English. Prior to beginning an interview, interviewees were asked if they would like their identity to be confidential, if they were comfortable having the interview recorded, and if they were comfortable being quoted. All interviewees agreed to have their interviews recorded and nine preferred to remain anonymous (Appendix 1).

The interview recordings were transcribed and coded by two university researchers using principles from thematic content analysis using NVivo 12 software. NVivo helped identify reoccurring themes and quantify the numbers of times they occurred by sorting and coding the data. Preliminary results were drafted and discussed (by phone) individually with Susie and three Elder interviewees identified by the OHTC as being particularly knowledgeable of Arctic char, and who shared substantial information during their interviews (J. Akhiatak, D. Kuptana, and G. Kudlak). These conversations helped to clarify uncertainties in the data, interpret findings, and provided additional details. Furthermore, some of the researchers returned to Ulukhaktok in May 2023 and in February 2024 and reviewed the updated results and draft paper in-person with these knowledge holders and others, to clarify ambiguities and add detail to help explain key phenomena.

Given that the themes and processes identified in this analysis involve interpretation of raw data, and given that the original expressions provide particular insights, the presentation of findings includes direct quotes to illustrate how the information was originally shared and how the broader context was seen by the interviewee. Interview data are complemented, when available, with data from secondary sources of information including, instrumental records, and literature (e.g., community reports, journal articles, government publications).

Research Limitations

A limitation of the hybrid interview model is that some interviewees had difficulties hearing the researcher(s) on the speaker phone, so we relied on Susie to lead some interviews. This limited the amount of probing, clarifying, and further questioning that the researcher(s) could do, but it also allowed Susie to conduct the interviews more freely. Susie actively fishes for Arctic char and was able to direct interviews

TABLE 2. Interview guide highlighting key themes and example interview questions.

Theme	Example questions
Knowledge of Arctic char	• Can you describe a healthy-looking Arctic char? • Could you walk me through a typical day of char fishing from start to finish? • Are there different types of char (within and among populations)? How do they differ? • What are the Inuinnaqtun words for the different types of char?
Changes observed	• Have you seen any changes in sea-run char in recent years (within the last 5 years) that concern you? Can you describe these changes? • Have you noticed any changes in the environment (freshwater, the land, coastal environment) within the last 5 years? • Can you describe how these changes have affected you and your family?
Responding to change	• Are you doing anything different because of these changes?
Future management and research	• Do you think more could be done to manage the char fishery? • Is there any research you'd like to see in the future?
Concluding questions	• Is there anything that we haven't talked about that you think is important to share? • Do you have any questions for me?

naturally and engage with detailed information about Arctic char that perhaps would not have been shared had the interviews been solely conducted by the researchers. Another limitation of the inability to conduct in-person data collection was not being able to observe or participate in the Arctic char fishery during that season. Participant observation is often used to gain an insider perspective on the topic being studied and to help contextualize the information shared during interviews. Place-based interviews also have the potential to illuminate and enhance the research experience, with the place and activity (e.g. fishing) acting as a cue for discussion on the topic. In this case, the research had to draw upon the past experiences of the research team, some who have spent a considerable amount of time (<20 years) periodically living in the community, participating in the Arctic char fishery, and have conducted TEK, climate change, and Arctic char research.

RESULTS

The results are presented in three sections, beginning with observed changes in individual Arctic char and then onto changes in the local environment which are surmised to be responsible for these changes, including the disruption of fishing activities (Tables 3 & 4). Current responses are discussed in the context of fisheries co-management and longer-term conservation. The content of each section is dealt with independently for the purpose of presentation, but it is recognised that information within each theme often overlaps.

Ulukhaktomiut Observations of Changes in Individual Arctic Char

Abundance, physical health, and appearance: All interviewees reported poor fishing for coastal summer and late fall fisheries, particularly between 2018–22. There was a sense of discouragement about the reduced catch of Arctic char with many interviewees struggling to reach their personal subsistence goals during these fishing seasons. An Elder interviewee mentioned that they forwent the coastal char fishery in recent summers because they had caught so few fish the previous year, and the early season fishing had also been poor (Interviewee #25). However, in the fall of 2023 (last week of August), some people caught a good number of medium-sized Arctic char in their nets set near the settlement, within a few days, enough to meet their subsistence needs. "The fish came back close to the shore when the water got colder, must be. Lots of nice sized ones late in the season" (Interviewee #26). One interviewee shared that they were not overly concerned about changes in Arctic char abundance since they believed that change is a part of all wildlife cycles.

> From what traditional knowledge has taught me, and from what Elders have passed down, yeah it changes [char migration] every few, quite a few years, every couple of decades, three to four decades. Animals change their migrations and make it hard for a while, and eventually make their way back.
>
> Laverna Klengenberg, #21

When interviewees were asked if they thought that individual Arctic char were physically healthy, six replied that they thought that they were healthy whereas others described an increasing occurrence of scars and sores on fish, and fish dying sooner in the nets. While some scarring is to be expected on anadromous Arctic char (e.g., injury from a predator), interviewees reported seeing more scarring than usual, with some fish appearing very damaged. Agnes Kuptana (#17) explained that some of the increased scarring was from swimming under the ice in the springtime; there is more young sea ice in the spring that is pushed in and out from the shoreline by strong winds.

> it [scarring] is to do from swimming under the ice, so much ice. Swimming along shallow places and the ice is coming in and out of the shoreline and they are getting cut under that.

Jean Ekpakhoak (#15) further explained that while she used to say that scars came from broken ice as char go down rivers, some of the scarring she is seeing today is different:

> ...you know when you scrape your skin, like the whole skin off the top of your skin, and it starts to get red and pus, not scratched but scrapped out?

Four interviewees observed open sores on the outer skin of some fish, and red and white spots, that when cut open excreted white pus. People will eat the fish with scars by removing those pieces of meat, but not the fish with spots, or sores on the meat as they are perceived to be unhealthy.

> I always want to find out what those little spots in the fish, when you cut them open, those white little dots. I've seen those a lot, and I have to start all over and wash the ulu and yours hands, and start all over. I don't cut those [fish] with white pus on them.
>
> Interviewee #22

It was reported that Arctic char are dying sooner after being caught in the nets during the summer and their flesh is softer due to warmer ocean temperatures; it is now typical for fish to die in nets within an hour, whereas in the past, they would stay alive much longer. Fishers must now set their nets where they can actively monitor them (e.g., in front of their houses/camp), or risk finding a net full of dead fish.

> We used to have frozen hands when we did nets, long ago, really cold. Now, we don't really get cold hands anymore. Then fish get soft cause the water is warm.
>
> David Kuptana, #6

TABLE 3. Summary of Inuit observations of changes in individual anadromous Arctic char in Ulukhaktok, Northwest Territories, Canada.

Observed change	Description of change	Sample quote
Abundance	• Fewer fish being caught	"...that would be the most significant change, the amount that we've seen, and the amount we've harvested, and amount that people have harvested, is a lot less." – Laverna Klengenberg, Adult
Physical health	• Increased scarring • Red and white spots on outer skin; excrete white pus • Fish dying sooner in nets; softer flesh	"We used to always wonder why they had so many scars and spots, and the Elders always told us it's when spring thaw comes and they are going to leave the lakes too early they get scarred up from the ice going down the river." – Jack Akhiatak, Elder
Appearance	• Colour of the meat has changed—from dark red-orange to pale orange	"...the only thing I really noticed is the colour of the meat has changed. It's not the same...now the dark red is becoming orange, or pale, or pink." – Agnes Aleekuk, Elder
Movement Patterns	• Earlier spring run • Some char staying in the ocean • Some char moving elsewhere • Catching char presumably from southern parts of Victoria Island	"Right now, not much snow and not going to be much water in the rivers. So, they [Arctic char] are not going to be able to travel anymore...other rivers here...there is barely any water. The fish can't even swim up to where they use to go up." – David Kuptana, Elder
Taste	• Char believed to be from Cambridge Bay and Kugluktuk taste 'muddy'	"...when you get those really white meat and you want to have fish so you cook it as soon as you get it, you kinda taste it like it has a muddy taste because our char doesn't taste that way." – Jean Ekpakhoak, Elder
Size	• Fewer medium-sized fish—fish >60cm (>24 inches)	"It's just like when we get fish, there's not too many smaller size that we like to catch. It seems like there is more bigger fish when we set nets in the ocean now." – Colin Okheena, Elder
Diet	• Char might be feeding more on sand lance and less on juvenile cod	"Those [sand lance] and little cod, those were usually always found in the char stomachs in the summertime. But, quite a few times now we are seeing mainly sand lance, which seems to be from what I heard, a less nutritious fish." – Gibson Kudlak, Elder

TABLE 4. Observed changes in the local environment and perceived impacts on Arctic char and the fishery.

Environmental change	Description	Implication for Arctic char & fishery
Salmon	Increasing prevalence of Pacific salmon.	• Less desirable than Arctic char. • Concern that salmon could be outcompeting Arctic char.
Temperature	Warmer air and marine sea surface temperatures.	• Fish die sooner when caught in nets. • Flesh is softer—mushy (less desirable).
Ice Conditions	Earlier sea-ice break-up, later freeze-up.	• Char are entering the ocean earlier in the spring. • Broken multi-year ice has inhibited setting nets on the shoreline.
Weather	Increased frequency and intensity of strong winds and wave activity.	• Extreme weather prevent travel to fishing grounds and setting nets.
Water Levels in Rivers	Low water levels in some rivers, Less precipitation in the summer.	• Low water levels in rivers inhibits char movement • Anecdotal evidence of marine mammals and fish moving away from the area.
Tunicates, "Slime"	2019 tunicate bloom	• Clogged fishing nets making them ineffective.

Movement Patterns, Timing, and Origin: Eleven interviewees said that the timing of the early-summer Arctic char run (fish moving through community bays) and fish behaviour have changed.

> The rivers are starting to open early every year, sometimes as much as two weeks earlier than historically. We usually wouldn't expect to get char until the early part of July, now we're starting to get them in the ocean as early as mid or third week of June.
>
> Gibson Kudlak, #7

Earlier spring thaw and sea-ice break up allow Arctic char to reach the ocean quicker than before; consequently, harvesters are now setting their nets two to three weeks earlier than usual. It has been observed, however, that Arctic char are spending less time along the shoreline in the spring and summer, and out of the reach of nets, and more time swimming further away from the coastline. The starting time of the fall Arctic char run (mid to late August) was reported to be unchanged, but in fall 2023, fishers reported catching char in their nets as late as the first week of October, approximately 2–3 weeks later than expected. Interviewee #24 speculated that this might be explained by extremely low water levels in some rivers as a result of a very dry summer and permafrost thaw; Arctic char will get out of the rivers in the spring because of the melt but they might not be able to get back up the river in the fall. As a result, more Arctic char remained in coastal waters later in the fall. Others posited that Arctic char, because of low water levels in some rivers, were changing the lakes they were overwintering in—from Tatik Lake to Mayoklihok Lake (Fig. 1).

Five interviewees explained that there is another type of char that spends much of its life in the ocean and infrequently overwinters in lakes, known as *takgiukmuitak* (ocean char). These fish are described as being 'very round and huge', upwards of 4 feet (122 cm) in length and look different than other Arctic char that seasonally overwinter in lakes.

> ...I kinda believe that [there are] different char. I know some char stay in the ocean all year around, during the winter they stay in deep areas where they don't come close to forming ice or anything. Those char, I know they are different cause I have heard it in the past from my grandfather, he liked the ocean char more than the char they got from the lakes.
>
> Interviewee #10

Two interviewees had caught *takgiukmuitak* in their nets in past summers, others by line and hook in open water leads in the sea ice during the spring, while three had seen them swimming under their boats during the summer, and others, while not having caught them, recalled hearing stories about *takgiukmuitak* from their Elders.

Eight interviewees surmised that Arctic char stocks in the area are moving outside of their expected geographic ranges. Relatives of interviewees in Sachs Harbour or Ikaahuk on the west coast of Banks Island, NT have reported catching an increasing number of 'Ulukhaktok Arctic char' in their nets. Robert Kuptana (#16) explained that Sachs Harbour Arctic char look very similar to Ulukhaktok Arctic char, but they have slightly lighter skin colour, perhaps because "Banks Island is sandier than Victoria Island". Similarly, some fishers in Ulukhaktok believe that they are now catching Arctic char from other parts of Victoria Island such as Cambridge Bay as well as Kugluktuk due to the colour and taste of the meat. They explained that the meat colour of some fish caught was now a pale orange, whereas they would expect it to be a dark red-orange.

> One thing I did notice, is the coloring in the meat. When we use to go get char they use to be really red colour, now paler colour like orange. They don't get really dark red like they used to. People have been talking about that for quite a while now, they noticed the char they get aren't as red as they use to be.
>
> Agnes Aleekuk, #1

Jean Ekpakhoak (#15) went on to explain that no matter how you cook the fish, whether you boil or fry it, you cannot remove the muddy taste, suggesting that it was from Cambridge Bay or Kugluktuk.

> And when you get those really white meat and you want to have fish, so you cook it as soon as you get it. You kinda taste it, like it has a muddy taste, because our char doesn't taste that way. I noticed because I have had fish from Kugluktuk and Cambridge Bay before and it is kinda of a muddy taste. Even if you cook it, boil, fry it, it still has a different taste on it.

Interviewee #10 suggested that perhaps Arctic char were now more often traveling north instead of south when they leave Minto Inlet during their ocean feeding migration due to warming ocean temperatures and possible changing prey availability.

Fish Size and Diet: All interviewees discussed changes in fish size and reported catching fewer medium-sized fish (average length of medium-sized fish >60cm), a phenomenon that has been ongoing for decades (since the 1960s). Unlike in the past when large fish would come first and be followed by smaller-sized fish during the spring Arctic char run, now there only seems to be large fish with fewer medium-sized fish following. Large fish are more desirable in the commercial fishery, but less so by subsistence harvesters, who prefers medium-sized fish because of their taste and suitability for making *piffi* (dry fish).

> I like the medium ones—medium size...the really big ones are pretty fat. The medium ones aren't fatty and I use them to make dry fish. You don't want too much fat on them cause they get oily... and then they don't taste good when they dry.
>
> Agnes Aleekuk, #1

Furthermore, interviewees explained that many of the Arctic char caught during the fall in Tatik Lake in the last three years were smaller in girth and weight, at a time when they would expect to see 'healthy' fatty fish after spending the summer months feeding in the ocean. Gibson Kudlak (#7) theorized that this could be due to a change in diet, from small cod to sand lance, which have become more common in the waters around Ulukhaktok.

Local Environmental Changes and Implications for Arctic Char and Fishing

Changes in the local environment were reported to have affected people's fishing activities and some may have implications for individual Arctic char movement and health. Some of these changes were discussed in the previous section (i.e., water temperature; water levels in rivers) and others are described here.

Pacific Salmon: The occurrence of Pacific salmon (*Oncorhynchus spp.*) has increased considerably in the waters near Ulukhaktok and across the ISR starting about twenty years ago and increasing in recent years (Dunmall et al., 2013; Dunmall et al., 2018; Chila et al., 2022). "... salmon is taking over. We see them all the time, most of the time, by the coast here." – Joseph Haluksit, #12. Interviewees were concerned about the reasons behind this increase in salmon and how this could affect Arctic char. In 2018 and 2019, interviewees reported catching an abundance of salmon (≈200) in their nets, but only a few (>10) were captured in 2020. Summer 2019 was unusually warm and the number of salmon caught was high, with David Kuptana (#6) reporting to have caught between four and six salmon a day in his nets for two weeks straight and only one or two Arctic char a day.

> We used to never get salmon! Now we are starting to get a lot of salmon. For us, it is a problem. People always say, 'when there is a lot of salmon, there's not much char,' and I believe that. All that salmon probably puts our char away too… The salmon have been around a while, but it was only a few numbers, just one caught a year or so. The summer before this one we got 200, so that is a really big jump. They are all over the ISR.
>
> David Kuptana, #6

Gilbert Olifie (#8) reported catching several salmon with eggs, suggesting that salmon were going to attempt to spawn in the area, and David Kuptana (#6) observed spawning colours in some of the salmon he caught in the ocean and during early winter fishing in Tatik Lake. One interviewee linked warming ocean and air temperatures, and changes in sea ice with the presence of salmon.

> I noticed a difference when there is sea ice around and the ocean temperature is colder. It was once cold on the hands even in the summertime after handling the nets for a few minutes. When the water is colder it seems to be little to no salmon around, but then when the ocean water warms up, the salmon come around.
>
> Gibson Kudlak, #7

Interviewees were generally unclear what impact salmon could have on Arctic char but one interviewee shared that salmon appeared to be more aggressive and territorial than char, and they were concerned that salmon are chasing char out of their spawning lakes and outcompeting them in the ocean.

> they [Pacific Salmon] are territorial, and they lay their eggs there, and don't want any other fish around their eggs so scare them away.
>
> Peter Alikamik, #9

Two interviewees said that they enjoyed the taste of salmon and will eat it opportunistically, whereas others said that they would not eat salmon. Jack Akhiatak, #11 explained that he will only use salmon as a substitute once his cache of Arctic char runs low. The thought of Arctic char becoming less abundant in coastal waters near Ulukhaktok was a commonly expressed fear. Interviewee #10 reluctantly foretold that her grandchildren and great grandchildren could become salmon eaters and no longer Arctic char eaters in the future, lamenting what this could mean for cultural continuity.

Ice Conditions: When temperatures warm-up quickly in the spring and the seasonal ice melts early, interviewees said that Arctic char move to deeper, cooler waters.

> It seems when there is ice around, there's more char. Where ice has virtually disappeared, then all the char disappeared for a while until fall time. Elders say, when the ice has disappeared, char go out into the ocean to go feed so they stay out there until fall time until it's time to go back to the lakes, rivers and they come rushing back to the shore.
>
> Interviewee, #10

In some recent years, winds have pushed broken pieces of multi-year ice close to the shoreline, possibly inhibiting Arctic char from traveling along the shoreline and from people accessing sites by boat to set nets along the shore.

> The fishing we do in the ocean is right on the shoreline... sometimes it is blocked from the multi-year ice...big jagged multi-year ice along the shoreline. The fish wouldn't be able to go near the shoreline. That is what we have a lot of this year, to the west of us anyway. That is where we do a lot of our fishing.
>
> Agnes Aleekuk, #1

Large jagged pieces of ice can freeze to the ocean floor, holding them in place along the shoreline, and take a full summer to melt or break free.

Weather: Interviewees reported an increase in the frequency and strength of both winds and wave activity during the summer months, and less precipitation during the winter months. These conditions impede travel to camping locations on the land, make it difficult, if not impossible, to set nets, and compromise nets that are set.

> Most of the time it's the weather, it gets too windy too fast. The swells come up, seem to come up faster.

> Usually you can wait them out, but it gets pretty scary if you try and come home if you have been out there too long, or if you don't realize there is rough water here.
>
> Agnes Aleekuk, #1

When people stay in the community to fish, they set their nets along the shores of the community bays and used to leave them in the water for weeks at a time while checking them regularly. Rougher water conditions are making this less feasible. Now, after just a few days of rough water, nets can become tangled and or filled with organic materials requiring them to be pulled out of the water and cleaned (Colin Okheena, #4). When people travel further away from the community to fish, the weather also plays a critical role. Some fishing locations are not safe to travel to at certain times of the year due to the fear of getting stuck in a storm and it is becoming increasingly difficult to set and check nets when the ocean is unsettled.

> Now, during the summertime it can be nice out in the morning and the wind comes out of nowhere during the day, and it could stay windy for days now. Where we use to have upwards of about a week sometimes, calm weather where we could plan a trip, now we go out sometimes, set up camp, and be stuck in camp for a week, and then go home when it is nice enough to go without doing too much.
>
> Gibson Kudlak, #7

Tunicate Bloom: In 2019, residents noticed a never before seen substance off the shores of Ulukhaktok, referring to the substance as "slime." After investigations in 2019, the slime was identified as a tunicate bloom (Pettitt-Wade et al., 2020). During the tunicate bloom, interviewees noticed marine mammals and fish seemed to move away from the area.

> …. It was all over the ocean. It was getting in our nets and leaving a brown slime and it seemed like it stayed until freeze up. It started happening until freeze up, as soon as we had ice out at the open water flow edge, started noticing them then. And then they stayed around all summer… They were all over the place, from the shore out to the deep.
>
> Gibson Kudlak, #7

The presence of tunicates posed challenges for effectively fishing in the ocean. The tunicates often clogged fishing nets making it nearly possible to catch fish and required fishers to pull their nets daily to clean them.

Ulukhaktomiut Responses to Changes in Arctic Char

At the individual level, Inuit in Ulukhaktok are adapting to changes in anadromous Arctic char through flexible fishing techniques, and changing the timing and location of their fishing activities. Some people are deliberately setting their nets in locations sheltered from wave activity and easily accessible from the land in the event of a storm. They are checking their nets more frequently and notifying each other if a net has become tangled or compromised by organic materials like tunicates. It is now more common for some harvesters to forgo setting nets near the community and instead travel to locations further south-east and north-west, closer to mouths of rivers used by Arctic char during migration, which used to be common practice before families moved to the current settlement (late 1960s-early 1970s) and is still practiced by some fishers. This requires additional planning, capital resource, time, and flexibility, given the unpredictability of the weather and sea ice, which has the potential to disrupt boat travel. Others forgo fishing in the ocean altogether and instead focus their efforts on net fishing under the ice at various lakes late fall/early winter.

Concerns about the health and abundance of Arctic char have triggered fisheries co-management responses. In February 2020, the UCWG, in consultation with the community, put a hold on the small-scale commercial fishing for the next five years to alleviate some harvesting pressure on the Tatik Lake population and prioritize the subsistence fishery. The commercial fishery was restricted to the summer coastal fishery only (mixed-stock) and typically overlaps spatially and temporally with subsistence harvesting. In February 2021, a year after the decision was made, interviewees had a lot to say about the decision to pause commercial fishing. Those who were supportive of the decision described how content they were and mentioned they had been asking the UCWG for years to temporarily pause the commercial fishery. They explained that commercial fishing can be hard on the Arctic char populations and compete with residents who struggle to reach their personal subsistence needs.

> We are thankful for that decision because people were not getting much char for themselves or for their households. People doing the commercial fishing were putting nets all over, so you know, this gives people a chance to get char. It really helps the community. Whoever got more fish than the other would share with the rest of the community and that is really great.
>
> Jean Ekpakhoak, #15

Interviewees who were against the decision explained that the commercial fishing was an important source of income for some people and taking this away from them would bring hardship. One interviewee explained that commercial fishing provides them with enough income to purchase gas and hunting supplies for the summer, which "puts food in the fridge and pays the bills" (Jack Akhiatak, #11). An interviewee who fishes for Arctic char for both subsistence and income and was a board member on the OHTC and the UCWG at the time of the decision expressed mixed emotions when it came to halting the commercial fishery. On the one hand, they were upset by the decision to pause the commercial fishery because they

enjoyed it as a source of extra income. On the other hand, upon reflecting, they realized that the future of the Arctic char fishery for subsistence was more important than short-term profits. Overall, interviewees shared confidence in the co-management system and general support for the actions taken, but some people also lamented the changes that are happening and the impact on fishing activities.

DISCUSSION

Inuit are on the frontline of Arctic climate change. The knowledge and observations documented here are a proxy of some of the changes occurring in the study environment and in Arctic char, which are continually being updated and revised in light of new experiences and information. It is for this reason that it is imperative that records of observed changes in Arctic char are continually updated, to inform flexible management decisions. Some important findings from this work include: i) changes in Arctic char quantity, quality, and health; ii) changes in how harvesters access the fishery because of weather, ice/water conditions and cost of travel; iii) observations of ecosystem change (e.g. salmon and tunicates) and concerns about their potential impact on char; and iv) the voluntary measure by the community to reduce their commercial catch. The initiation of precautionary measures by the community is noteworthy as there are many other environmental stressors that are having a greater negative impact on Arctic char than harvesting, but they are difficult, if not impossible, to control (e.g., warming temperatures). Harvest numbers were much higher in the past (Lea et al. 2023b) and were considered to be sustainable, but under new environmental conditions and lower stock numbers, the same level of harvest may no longer be feasible or sustainable.

Our findings complement existing documentations of changes in Arctic char in the Ulukhaktok fishery (e.g. Paylor, 1998; Knopp et al., 2010; Harwood et al., 2013; Gallagher et al. 2021; Lea et al., 2023a). For instance, previous research documented Inuit observed changes in the quality of Arctic char flesh in Sachs Harbour and Ulukhaktok (Knopp, 2010), and changes in the colour and taste of Arctic char caught elsewhere in the Amundsen Gulf (Steiner et al., 2019) laboratory experiments and models to showcase how the integration of scientific methods and indigenous knowledge can improve our understanding of (a. Gallagher et al. (2021) and Lea et al. (2023a) documented changes in the size of Arctic char between the 1990s and the mid–2010s, with fewer smaller-sized fish caught and increases in growth rates in later years, in seasonal Ulukhaktok subsistence fisheries. These findings are consistent with the trends observed in data collected from the Tatik Lake Char Monitoring Program collected during the winter fishery in 1991 and 1993–2015 as well as data from sampling conducted in 1978 and 1987, with fewer medium-sized fish caught and increases in growth rates in the latter years (DFO, 2016). Other studies completed with fishers in the ISR have reported recent declines in Arctic char abundance, such as Paulatuk (Lede et al., 2021)and its impacts are being experienced by human communities in the context of other environmental and societal stressors. This paper argues that an assessment of human vulnerability to climate change requires knowledge of these stressors, including the interactions among them that influence people's sensitivity to climate risks and adaptability. This paper examines the role of multiple stressors in adaptation to climate change through a case study of Paulatuk, Northwest Territories, Canada. It is based on collaborative research involving semi-structured interviews with 28 participants, participant observation, and analysis of secondary sources of information. In the context of subsistence harvesting, climatic stressors have affected access to, and the availability of, some fish and wildlife and are making travel conditions more unpredictable and dangerous. These stressors are being experienced at the same time as societal stressors such as financial and social barriers to participating in subsistence, challenges with local schooling, lifestyle changes, housing shortage and overcrowding, and addiction. Many of the coping strategies used by people in Paulatuk to deal with stressors involve trade-offs, such as leaving the community for school or leaving school to participate in subsistence and switching species harvested in response to a decline in one species, which has undermined resilience to other stressors. This research demonstrates the need to consider the role of pre–existing environmental and societal stressors and diversity within communities in climate change adaptation planning in the Arctic. Similar phenomena have been observed in Nunavut, where fish caught were much larger than expected, had pale pink flesh, and were described as tasting different than what was expected (Zerehi, 2016). In Kugluktuk (Smith, 2020) and Cambridge Bay (Gilbert et al., 2020), warming ocean temperatures may be affecting migration patterns and timing.

Additionally, this research presents new findings that have not previously been documented. One such finding is fish health according to Inuit, including increased scarring, small red and white sores on the outer skin, and fish rapidly dying more quickly once captured in nets during summer. There is also TEK that looks at different characteristics of the fish like appearance (on the outside and the inside), taste, size, direction that it's swimming, and timing, that might indicate the origin of the fish, but further work is required to understand these indicators of stock origin. Since the higher prevalence of Pacific salmon is a relatively new phenomenon in the Canadian Arctic, there is minimal literature on Inuit perception of salmon (see Chila et al. 2022). The data reported here show that there is a great deal of uncertainty about the potential impact of salmon on Arctic char and different perspectives on the consumption of salmon. Changes in the movement ecology of Arctic char have been noted previously, specifically the timing of migration (e.g. Gilbert et al., 2016), and our study goes further to discuss the earlier timing of the summer char run,

movement of char outwards from the coast, and elsewhere in the region, the prevalence of char in coastal waters later in the fall, possibly in relation to lower water levels in rivers and warmer ocean temperatures, and the possibility of Arctic char returning to different overwintering lakes. These finer observations of changes in movement ecology show the potential of TEK to help contextualize phenomena captured by quantitative studies (e.g., Hollins, et al. 2022) and generate new questions and hypotheses that could guide future research. For example, if some Arctic char are switching overwintering lakes, could this have implications for energy dynamics and subsequently for the timing of the char run (when char reach fish nets set by Inuit)? What do we know, in terms of life cycle, feeding behaviour and movement ecology, about the type of Arctic char that Ulukhaktomiut say spends most of its life in the ocean, *takgiukmuitak*?

Some changes and impacts presented in this research are direct observations by Inuit, whereas others are inferences. The topic of Pacific salmon is a key example. The increasing occurrence of salmon is a direct observation made by most interviewees; however, the idea that salmon negatively impact Arctic char may be based on a degree of inference and speculation. Most interviewees believed that salmon have a negative impact on Arctic char although they have not directly observed these fish interact. This finding can be explained by the nature of TEK, which pursues holism through the continued reading of the environment, collection of large amounts of information, and the construction of collective mental models that can adjust to new information. Inuit may not have directly observed a phenomenon, but they are able to generate knowledge about it using mental models (Berkes and Berkes, 2009).

The research findings emphasize the importance of dynamic and flexible co-management organizations and documenting local TEK of change to inform resource management. The structure of the UCWG's decision-making process demonstrates the value of adaptive co-management, and the importance of community voices in decision-making. Inuit voices and knowledge are captured in decision-making related to Arctic char in two ways: the first is through appointed residents sitting on the UCWG, and the second is through the community feast and public meeting held in conjunction with the UCWG meetings. These public meetings hosted by the UCWG provide an opportunity for community members to learn about what was discussed, hear the results from the scientific community-based research programs, ask questions, provide recommendations to the Working Group, vocalize their concerns, and make collective decisions. This research is a recorded summary of community member's TEK of Arctic char under changing climatic conditions that is intended to be used alongside scientific findings and resident's oral contributions to help inform UCWG management discussions.

CONCLUSION

The primary objective of this research was to document Inuit TEK of anadromous Arctic char under changing climatic conditions, implications for seasonal fisheries, and the response of harvesters. The research demonstrates that Inuit are astute observers of changes, captured over multi-decadal time series, in their local environment and possess detailed knowledge of Arctic char. It also underscores the response of harvesters to these changes, notably prioritizing subsistence, and showing flexibility in fishing location, timing, and technique. Ultimately, the goal of co–management processes is to use the best available TEK and science for decision making, which is challenged even further by rapid climate change. Inuit have generated hypotheses to help explain these changes (e.g. linking lower water levels in rivers and warmer ocean temperatures with changes in migration patterns and timing), but seek additional mechanisms for testing them. The TEK documented here could help guide future collaborative research and monitoring efforts. The use of the two approaches, TEK and science, together provides an opportunity to identify domains of complementarity, which can be harnessed to take advantage of their relative strengths. The information generated could be used to inform new research directions, harvest monitoring programs, and co-management bodies to help protect vital Arctic char fisheries for Inuit.

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