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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, health, and movement ecology (an understanding of home range and movement patterns) 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, which 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, as well as broader environmental changes that disrupt fishing activities. These changes include: an 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

RÉSUMÉ. **Les Inuits de l'ouest de l'Arctique canadien observent les incidences du changement climatique sur l'environ**nement marin et l'environnement d'eau douce, se traduisant par des changements en matière d'écologie de l'abondance, de la santé et des déplacements (la compréhension des modèles de déplacement et du domaine vital) de l'omble chevalier, *iqalukpik* (*Salvelinus alpinus*) et par des conséquences sur leurs pêches. Cette recherche a été conçue en collaboration avec les Inuits afin d'enquêter sur les changements caractérisant l'omble chevalier anadrome dans les eaux environnantes d'Ulukhaktok, dans les Territoires du Nord-Ouest, au Canada. L'analyse d'entretiens semi-structurés réalisés auprès de 26 pêcheurs inuits a permis non seulement de documenter les changements en matière d'abondance de la population, de déplacement spatial, d'apparence et de goût de l'omble chevalier, mais aussi les changements en matière d'accès aux pêches. Au cours des dernières décennies, et de manière plus prépondérante ces dernières années, un moins grand nombre de poissons, plus particulièrement de poissons de taille moyenne, qui font la préférence des pêcheurs, ont été pêchés à l'aide de filets près du peuplement, certains des poissons se trouvant dans un mauvais état corporel et d'autres semblant provenir de lacs situés à l'extérieur de la portée géographique attendue, plus tôt dans une saison de pêche côtière estivale prolongée. Les Inuits observent des changements sur le plan des poissons individuels de même que des changements généraux de nature environnementale perturbant les activités de pêche. Parmi ces changements, notons une plus grande prévalence de saumon du Pacifique, des températures de l'air et des températures de surface de la mer plus chaudes, des conditions de glace de mer et de lac inégales, des vagues et des vents plus forts et plus fréquents, la fluctuation des niveaux de l'eau des rivières et la floraison saisonnière des tuniciers. Les Inuits réagissent à ces changements en modifiant leurs pratiques personnelles de pêche de subsistance et en interrompant

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temporairement les pêcheries commerciales communautaires de petite échelle à la lumière des observations de la diminution du stock de poissons et de la priorisation de la pêche de subsistance.

Mots-clés : adaptation; pêcheries; Autochtone; Inuvialuit; subsistance, 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 peoples' 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 fisheries large and small, whether they are commercial, subsistence, or recreational, and will affect fishing patterns, processes, and resilience. To cope, Arctic people must develop adaptive management responses to conserve and protect not only aquatic species, but also the livelihoods of people who rely on them (Badjeck, 2010; Moerlein and Carothers, 2012; Brinkman et al., 2016; Hunt et al., 2016; Shaffril 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 in patterns of 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 what are known as their life history characteristics, among them growth, reproduction, and migration. These effects can be particularly acute for anadromous species, which move between freshwater (breeding) and marine (feeding) habitats and must contend with added complexities of the changes exacerbating deteriorating conditions across 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 et al., 2017).

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: some undertake seasonal migrations between freshwater and highly productive marine habitats (anadromous), and some remain in freshwater throughout their lifespan (resident) (Johnson, 1980; Jonsson and Jonsson, 2001). Since their life history characteristics are highly influenced by environmental conditions, habitat use, and food consumption, Arctic char are a strong indicator of environmental change (Reist and 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 and 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 fresh water 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 food source rich in nutrients (e.g., long-chain omega-3 polyunsaturated fatty acids), 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 (i.e., net fishing under ice). For Inuit, Arctic char represent self-sufficiency in food security and the traditional subsistence lifestyle (Condon et al., 1995; Reist et al., 2018). Arctic char also play a central role in Inuit food sharing networks and managing social relations (Knopp et al., 2012; Condon and 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 (fish caught per standard unit of effort), and biological information about Arctic char from long-term (30 plus-year, 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; Finstad 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 in a changing climate, including Arctic char, 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; Pearce et al., 2015). 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 tends to focus on long time series (Moller et al., 2004). TEK strives for an understanding of 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; Pettitt-Wade et al., 2020). For these reasons, resource managers in the Arctic (e.g., Dubos et al., 2023 for Nunavik and Farladeau et al., 2022 for Kitikmeot region), and elsewhere (e.g., Butler et al., 2012 for 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 effects 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 on the west coast of Victoria Island in the Inuvialuit Settlement Region (ISR), Northwest Territories, Canada (70˚45′42″ N, 117˚48′20″ W) (NWT Bureau of Statistics, 2019) (Fig. 1). Historically, the region was home to the Northern Copper Inuit, who are known for their migratory seasonal hunting and nomadic lifestyle (Condon and 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). According to a community survey conducted in 2019, 79% of residents participate in traditional hunting and fishing activities, and 47% of the population draws the majority of the meat and fish they consume from 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 and Bennett, 2019), and fish, including Arctic char, are of high importance (Ayles et al., 2007; Olohaktomiut Hunters and Trappers Committee, et al., 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 and early winter at the lakes used as overwintering habitat. Contemporary harvest surveys (2004 – 15) revealed that 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). Separately, approximately 200 resident (landlocked) Arctic char are harvested annually from under lake ice during spring (Lea et al., 2023b). Regardless of the season, when Inuit harvest Arctic char, they will either consume the fish immediately, prepare and store it for future consumption (e.g., dried (*piffi*), frozen raw (*quaq*), or smoked), or distribute it to family members in the community and living elsewhere; Arctic char play a fundamental role in community sharing networks and social relations (Condon and Ogina, 1996). Arctic char's value has also evolved to hold economic importance since 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). This fishery, founded in 2000, had an original quota of 100 fish, which rose to 500 fish the next year (2021), and again to 700 fish in 2016, remaining at that number until the fishery was put on hold in 2020 (Lea et al., 2023a).

The ISR was created in 1984 with the signing of the Inuvialuit Final Agreement, a land settlement agreement between six Inuit communities and the Canadian Government. The Inuvialuit Final Agreement 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 agreement, including the Wildlife Management Advisory Council (Northwest Territories), Fisheries Joint Management Committee, Inuvialuit Game Council, and Inuvialuit Hunters and Trappers Committees (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). Due to such stock depletion, in the early 1990s, the community voluntarily closed Tatik Lake (fed by the river) to all fishing between 1993 and 1995 (DFO, 2016). In response to this concern, the Department of Fisheries and Oceans (DFO), Fisheries Joint Management Committee, and Olokhaktomiut Hunters and Trappers Committee (OHTC) established the Holman (now Ulukhaktok) Char Working Group (HCWG or UCWG) to monitor changes to Arctic char stocks. 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

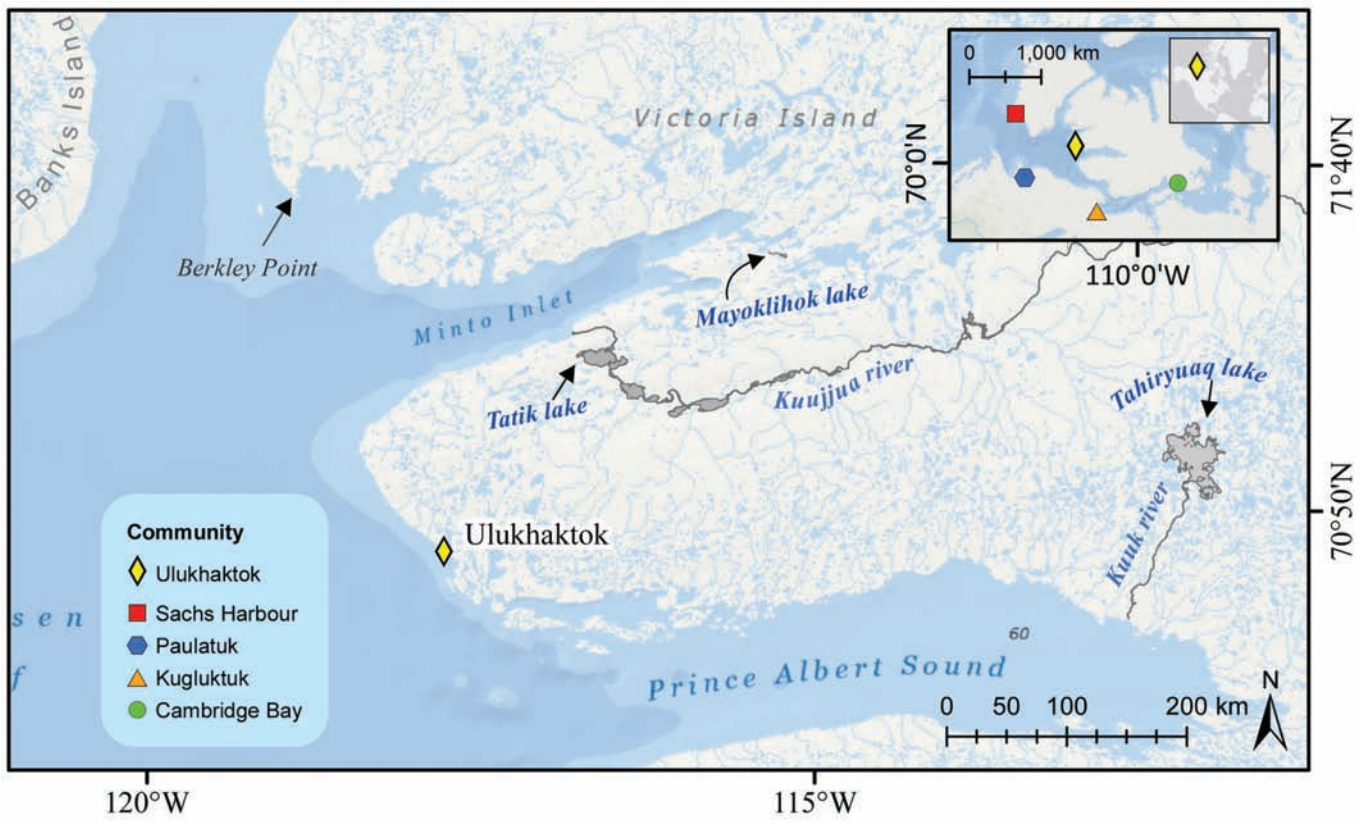

FIG. 1. Key locations related to Arctic char habitat and fishing in the Amundsen Gulf, Canadian Arctic (main map). Location of Ulukhaktok relative to other Inuit communities (inset map). Service layer credits. Sources: Esri, GEBCO, NOAA, National Geographic, Garmin©, OpenStreetMap contributors, GIS user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

all pertinent information back to the DFO, the Fisheries Joint Management Committee, and hunter and trappers committees at the regional level to inform decision-making. 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 paths forward. The UCWG uses an adaptive co-management approach (i.e., pluralistic, with shared decision-making) that combines traditional and scientific knowledge in the management and monitoring of Arctic char.

In 2019, the UCWG requested research to document TEK of anadromous Arctic char under changing climatic conditions and implications for the fishery. The goal was to use TEK to complement existing scientific knowledge and help guide future monitoring and research directions (e.g., by generating new research questions, building new hypotheses, expanding understanding of complex systems, and establishing 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 effects on anadromous Arctic char and community fisheries; and 3) discuss individual harvester and community-level responses. This study expands on previous research with Inuit in Ulukhaktok that recorded TEK of Arctic char under changing climatic conditions (Paylor, 1998; Knopp, 2010).

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 outlined 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 who 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. The OHTC and researchers made a list of potential interviewees that took into account 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). They took place between 16 February and 11 March 2021 at the interviewee's home or at the OHTC office, with university researcher(s) participating via speaker phone. Some interviews were arranged by Susie but conducted solely by university researchers. For flexibility, interviews were semi-directed, unfolding in a conversational style using open-ended questions, allowing the interviewee to freely speak about topics and concerns important to them (Hay, 2016) (Table 2). A list of topics, themes, and questions were used as a reference guide (Huntington, 1998) (Table 3). 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).

Two university researchers transcribed and coded the interview recordings based on principles of thematic content analysis and using NVivo 12 software. By sorting and coding the data, NVivo helped identify reoccurring themes and quantify the number of times they occurred. Preliminary results were drafted and discussed (by phone) individually with Susie and three Elder interviewees identified by the OHTC as being particularly knowledgeable about Arctic char, and who shared substantial information during their interviews (J. Akhiatak, D. Kuptana, and G. Kudlak). These conversations helped by adding additional details, clarifying uncertainties in the data, and allowing interpretation of the findings. Furthermore, some of the researchers returned to Ulukhaktok in May 2023 and February 2024 and reviewed the updated results and the 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).

TABLE 1. Demographic characteristics of interviewees in Ulukhaktok.

Age cohort	Gender		Totals
	Female	Male	
Young adult (18–34)	0	0	0
Adult (35–54)	6	1	7
Elder (55–74)	7	9	16
Oldest Elder (75+)	1	2	3
Totals	13	13	26

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 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 members of which have spent a considerable amount of time (> 20 years) periodically living in the community and participating in the Arctic char fishery, and who have conducted TEK, climate change, and Arctic char research.

RESULTS

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 and 2022. There was a sense of discouragement about the reduced catch of Arctic char, with many interviewees struggling to

TABLE 2. 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 • Increased scarring • Red and white spots on outer skin; excrete white pus	"... 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	• 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 • Earlier spring run • Some char staying in the ocean • Some char moving elsewhere	"... 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	• 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 ... [in] 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 >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

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 individual Arctic char were physically healthy, six replied that they thought 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., due to 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, pointing out that today, there is more young sea ice than in the past at that time of year, which gets 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 scraped out?"

TABLE 3. 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 five 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 five 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?

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

Some participants reported that Arctic char are dying sooner after being caught in the nets during the summer and that 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 or 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).

Movement Patterns, Timing, and Origin: Of the interviewees, 11 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 breakup allow Arctic char to reach the ocean quicker than before. Consequently, harvesters are now setting their nets two to three weeks earlier than usual. However, participants conveyed a general consensus 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 farther away from the coastline. Participants said the starting time of the fall Arctic char run (mid- to late August) was unchanged, but in fall 2023, fishers reported catching char in their nets as late as the first week of October, approximately two to three 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 which lakes they overwinter in, from Tatik Lake to Mayoklihok Lake (Fig. 1).

Five interviewees described another type of char known to the community as *takgiukmuitak* (ocean char), which they said spends much of its life in the ocean and infrequently overwinters in lakes. These fish are described as being "very round and huge," upwards of 4 feet (122 cm) in length (Interviewee # 22) and different looking than other Arctic char that do 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 had done so 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 still 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 who live in Sachs Harbour or Ikaahuk, on the west coast of Banks Island, Northwest Territories, 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 have a slightly lighter skin colour, perhaps because "Banks Island is sandier than Victoria Island." Similarly, some fishers in Ulukhaktok believe 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 was now a pale orange, whereas they would expect it to be a dark red-orange.

> One thing I did notice, is the colouring 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 prepare those kinds of char, you cannot remove the muddy taste, suggesting that they are 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 travelling 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 seem to be large fish, with fewer medium-sized fish following. Large fish are more desirable in the commercial fishery, but less so for subsistence harvesters, who prefer medium-sized fish because of their taste and suitability for making *piffi*.

> 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

Interviewees also 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

Changes in the local environment were reported by interviewees to have affected people's fishing activities, and some may have implications for individual Arctic char movement and health. Besides changes in water temperature and river water levels touched on above, interviewees described several more local changes.

Pacific Salmon: The occurrence of Pacific salmon (*Oncorhynchus spp.*) has increased considerably in the waters near Ulukhaktok and across the ISR. This increase began about 20 years ago and has accelerated in recent years (Dunmall et al., 2013, 2018; Chila et al., 2022). Interviewees noted this dramatic change: "...salmon is taking over. We see them all the time, most of the time, by the coast here" (Joseph Haluksit, #12). Many were concerned about the reasons behind this increase in salmon and how this could affect Arctic char. Interviewees reported that in 2018 and 2019 they caught an abundance of salmon (≈ 200) in their nets, but that in 2020, they only caught a few (>10). Summer 2019 was unusually warm, and the number of salmon caught was high, with David Kuptana (#6) reporting that he 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 about what impact salmon could have on Arctic char, but one person 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 they enjoyed the taste of salmon and will eat it opportunistically, whereas others said 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: Interviewees said that when temperatures warm up quickly in the spring and the seasonal ice melts early, 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 travelling along the shoreline and preventing people from 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, which holds them in place along the shoreline; it can take a full summer for them 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. Until recently they would 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 or filled with organic materials, requiring people to pull them out of the water and clean them (Colin Okheena, #4). When people travel farther 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 impossible 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 by 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. This used to be common practice before families moved to the current settlement (in the late 1960s and early 1970s) and is still practised by some fishers. But travelling requires additional planning, capital resource, time, and flexibility, given the unpredictability of the weather and sea ice, which have 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 during late fall and 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 that 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 can 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 fishery 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 reflection, 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 environmental changes their region is experiencing 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. This knowledge is continually being updated and revised in light of new experiences and information people gather. 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 (Table 4). Some important findings from this work include: 1) widely observed changes in Arctic char quantity, quality, and health; 2) changes in how harvesters access the fishery because of weather, ice and water conditions, and cost of travel; 3) observations of ecosystem change (e.g., salmon and tunicates) and concerns about their potential impacts on char; and 4) mostly positive analysis among fishers of a voluntary measure by the community to reduce their commercial catch, despite their real concerns over lost income. 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 documentation of changes in Arctic char in the Ulukhaktok fishery (e.g., Paylor, 1998; Knopp, 2010; Harwood et al., 2013; Gallagher et al., 2021; Lea et al., 2023a). For instance, previous research documented Inuit-observed changes in the quality

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

Environmental change	Description	Implication for Arctic char and 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 breakup, later freeze-up	• Char are entering the ocean earlier in the spring. • Broken multi-year ice has inhibited setting nets on shoreline.
Weather	• Increased frequency and intensity of strong winds and wave activity	• Extreme weather prevents 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.
Tunicates, "slime"	• 2019 tunicate bloom	• Anecdotal evidence of marine mammals and fish moving away from the area. • Clogged fishing nets making them ineffective.

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). Gallagher et al. (2021) and Lea et al. (2023a) documented changes in the size of Arctic char between the 1990s and the mid-2010s in seasonal Ulukhaktok subsistence fisheries, with fewer smaller-sized fish caught and increases in growth rates in later years. 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 changes to fish growth in the Hornaday River (Chavarie et al., 2019). 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 worsening fish health, which according to Inuit, includes increased scarring, small red and white sores on the outer skin, and fish rapidly dying once captured in nets during summer. Our research also documents TEK regarding different fish characteristics that might indicate the origin of Arctic char, like appearance (on the outside and the inside), taste, size, direction of swimming, and timing of migration. Since the higher prevalence of Pacific salmon is a relatively new phenomenon in the Canadian Arctic, there is minimal literature on Inuit perceptions 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). Our study goes further to discuss the earlier timing of the summer char run; movement of char outwards from the coast; the prevalence of char in coastal waters elsewhere in the region 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 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 environmental changes 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: first, through appointed residents sitting on the UCWG, and second, 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 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 members' TEK of Arctic char under changing climatic conditions that is intended to be used alongside scientific findings and residents' 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. We also sought insights on the implications for seasonal fisheries and the response of harvesters. The research demonstrates that Inuit are astute observers of changes in their local environment and possess detailed knowledge of Arctic char gathered intergenerationally over long time series. 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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