

## Article

# Fishing Livelihoods in the Mackenzie River Basin: Stories of the D  l  ne Got  ine

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**Abstract:** Climate change is among the greatest challenges facing Indigenous peoples. The impacts of climate change cannot be understood as only ecological or through models and projections. In this study, narratives from Indigenous peoples provide lived experience and insight of how social and ecological impacts are interconnected. Through collaborative research with the Saht   Renewable Resources Board in the Northwest Territories Canada in the period 2018–2019, this paper shares the stories of the D  l  ne Got  ine peoples of Great Bear Lake (GBL), and how warming temperatures in the region impact fishing livelihoods. Specifically, we address the question, “What are the impacts of climate change on the fishing livelihoods of the D  l  ne Got  ine people?” Narratives from 21 semi-structured interviews reveal insights on six dimensions of fishing livelihoods. Analysis suggests the specific indicators of ecological change of concern to fishers and how those impact livelihoods over the short and long term. Given that the majority of research on climate change involving Indigenous peoples in Canada has focused on the high arctic and marine environments, this work is unique in its focus on the subarctic region and on freshwater ecosystems and livelihoods.

**Keywords:** fishing livelihoods; subsistence fishing; Great Bear Lake; climate change; traditional knowledge; oral histories; Canadian subarctic; Mackenzie River Basin; D  l  ne; Saht   Got  ine

## 1. Introduction and Literature Review

In 2007, the Intergovernmental Panel on Climate Change (IPCC) assessment concluded that the ‘impacts of large-scale and persistent changes are likely to include changes in marine ecosystem productivity, fisheries, ocean CO<sub>2</sub> uptake, oceanic oxygen concentrations and terrestrial vegetation’ [1]. Fisheries are food sources considered highly vulnerable to climate stress [2]. This is particularly true in northern regions as the effects of climate change are being felt earlier and more keenly in the polar latitudes than elsewhere in the world [3]. Among the peoples experiencing these impact are the Saht   Got  ine peoples of D  l  ne (formally known as Fort Franklin), situated on the west end of Keith Arm on Great Bear Lake (Saht  ) (Figure 1).

Research in the region in the period 2017–2018 built on previous ethnographic, sociological and ecological studies [4–7], as well as the broader literature on traditional knowledge and climate change [5,6]. Guided by local governance organizations (e.g., Saht   Renewable Resources Board), semi-directed interviews were conducted about past, present and future dimensions of fishing livelihoods. By asking questions about changes being observed and experienced, much was learned about how the health of fish, diversity and movements of species, fish habitat and fishing practices have changed over the last one hundred years as a result of warming seasonal temperatures, extreme weather events and changes in precipitation patterns (i.e., drying conditions). This work has contributed to local governance and individual and institutional understanding of changing Saht   territory and

land-based livelihoods. We have also aimed to contribute to theories and literature on climate change effects including theories on the value of traditional knowledge of Indigenous peoples in dealing with a changing climate [4].

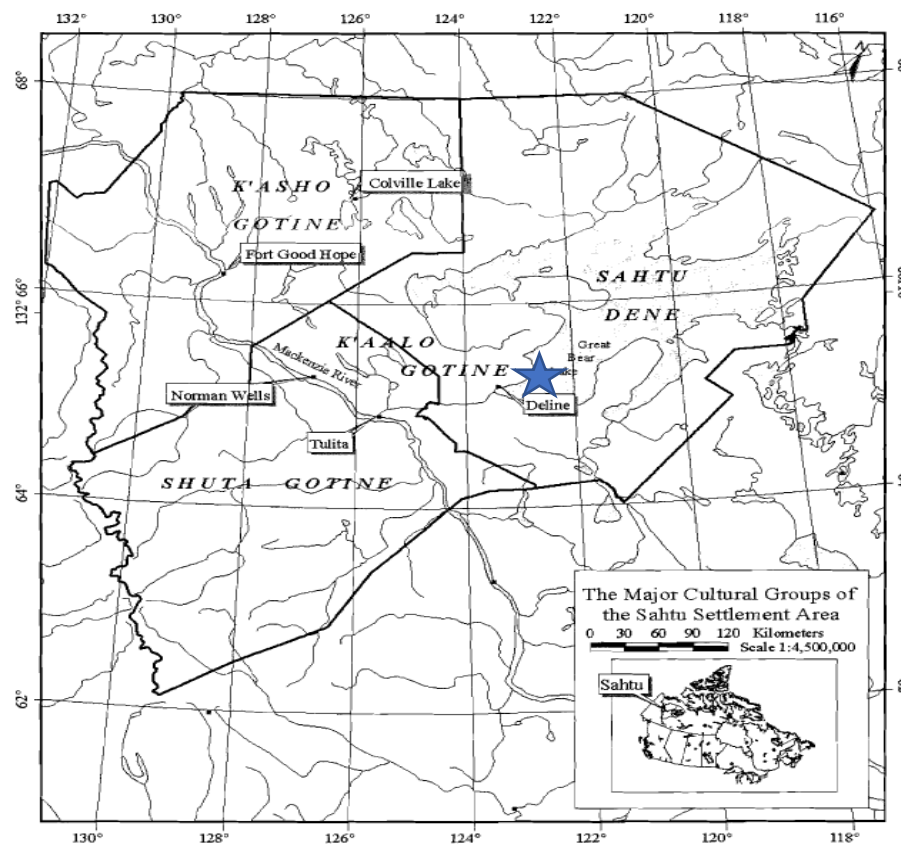


Figure 1. A map showing Sahtú regions and study area.

Over many generations, the Sahtú Got'ine have developed significant knowledge, practices and beliefs about how to live well in their environment [8]. This accumulated traditional knowledge associated with their local ecosystems has been critical to the sustainability of fishing livelihoods, and has enabled the community of Deline to thrive over many hundreds of years. However, climate change-related issues and an increasing number of uncertainties in environmental conditions (e.g., abnormal environmental events) are increasingly evident. This paper describes these impacts as well as illuminates how such uncertainty impacts on fishing practices as well as the long-term sustainability of fishing livelihoods and the associated traditional knowledge of the Sahtú Got'ine people.

Although a significant body of knowledge is developing about climate change in the arctic, few studies have focused on the climate-related knowledge and experiences of Indigenous peoples of the subarctic region including those living in the Mackenzie River Basin of western Canada. Through collaborative research with the Sahtú Got'ine of the Great Bear Lake, this paper aims to address this gap, with a particular focus on the livelihoods of Sahtú Got'ine fishers.

In doing so, this paper also aims to make a modest contribution to the literature on traditional knowledge and fishing livelihoods. Although there is a large body of literature on this theme globally, this paper is unique in its specific focus on the Mackenzie River Basin. Findings from this project are also intended to expand understanding of how communities may, or may not be, coping or adapting to climate change. Given that fishing contributes significantly to the food security, cultures and economies of Indigenous peoples, these insights into adaptation have many implications. It is hoped that by

making these contributions, more community-led solutions can be developed in order to better mitigate the harmful impacts of climate change.

### 1.1. Great Bear Lake and the Sahtú Got'ine

Fishing is innately a part of who they are as Dene people, and in order to continue this distinct way of life, the Sahtú Got'ine believe that they must continue to respect the lake in order to maintain its pristine purity and resource richness. For example, *Sahtú Kehwey* translates to 'Great Bear Lake is the boss,' and it is a phrase that is constantly repeated around the community. This phrase reveals that the Sahtú Got'ine people understand how GBL regulates their life, while subtly affirming that their presence on the lake is essentially irrelevant: the Sahtú Got'ine need the lake; the lake does not need the Sahtú Got'ine. The underlying message of this expression is illustrated in their unrelenting need to set a net and provide food resources for the community. It is this particular worldview that drives fishing livelihoods in Délne and provides purpose for future generations to continue to maintain this culturally significant tradition.

Previous ethnographic research in the region has highlighted the complexity of traditional knowledge that has developed in the region as well as the wealth of oral history that underpins present day resource management plans and institutions such as the Sahtú Renewable Resources Board and the Great Bear Lake Management Plan [9]. Anthropologists such as Helm and Rushforth [10,11] describe the importance of fishing as part of the seasonal round of the local people. An evaluation of the importance of fish stocks to the diets of local communities has also been carried out as part of the Sahtú Harvest Study and related research [12]. Time and again, the tremendous value of the watershed and the associated fishery is highlighted by biologists and social scientists alike [13]. However, the lake and associated livelihoods of the Sahtú Got'ine people have been under stress over the last 100 years due to resource development including uranium mining as well as oil and gas activity [14,15]. Although not well documented to date, this study suggests that climate change is an added layer of stress on both the Great Bear Lake ecosystem as well as fishing livelihoods.

### 1.2. Traditional Ecological Knowledge and Fisheries Management

"Traditional ecological knowledge (TEK) is interpreted as a cumulative body of knowledge, practices and representations that describes the relationships of living beings with one another and with their physical environment, which evolved by adaptive processes and has been handed down through generations by cultural transmission" [16] (p. 1252). There are many ideas around the value of this knowledge to fishing livelihoods.

The relationship between TEK and available Western science around fisheries and climate change is also an important context for this paper. While there is much discussion about the value of TEK in understanding climate change at international scales, such lip service tends not to be visible at local and regional scales. For example, while there is often conflict between small-scale fjord fishermen and Danish seine fishermen, it is suggested that TEK can also complement and supplement policy [17]. Global institutions involved in fisheries governance are often disinterested in TEK, or lack understanding, so tend towards making decisions based only on Western science. As a consequence, power in fisheries management tends to be concentrated in the hands of Euro-Canadian bureaucratic structures, reflect only Euro-Canadian values and marginalize the voices of Indigenous peoples [16–18]. In the Northwest Territories, however, where Indigenous rights to harvest and TEK is recognized in legislation including land claim agreements, there is greater opportunity to learn from fishers and TEK holders. In Sahtú region, for example, the Sahtú Renewable Resources Board as well as regional authorities such as the Délne Government are strongly informed by the knowledge of local people. As climate change continues, the capacity of these institutions to adapt and learn from the observations and experiences of the Sahtú Got'ine becomes increasingly important.

## 2. Methods

This project is inspired by Dene teachings and stories of Sahtú community leaders and guided by a diversity of Indigenous and non-Indigenous scholars [19–22],

Research activities took place in Délne during the summer of 2017 in settings considered ecologically and culturally significant. While Berkes states that it is sometimes considered difficult to investigate and quantify subsistence fisheries, this paper defines it as “local, non-commercial fisheries, oriented not primarily for recreation but for the procurement of fish for consumption of the fishers, their families, and communities” [23]. In order to accomplish the task of identifying respected elders and knowledgeable youth, the project’s translator (Michael Neyelle) and community research collaborator (Mandy Bayha) played a major role. Twenty-one semi-structured interviews were conducted with various elders, fishermen and youth based on traditional and local knowledge. The first interview was conducted with Morris Neyelle because he is known within the community for his extensive knowledge and history on Great Bear Lake. He recommended other fishermen, women and elders to interview. The use of snowball sampling proved to be very effective for this project and allowed for flexibility in the interview process. Environmental changes surrounding fishing livelihood activities as well as perceptions and conceptions concerning climate change are the two main topics that emerged from interviews and form the basis of this thesis. Every interview began with a very broad question on personal history surrounding GBL and, based on the answer, the conversation shifted towards specific topics. For example, if interviewees discussed previous fish populations, probing questions surrounding present fish populations were asked as well as exploring their beliefs concerning current fish yields. An average interview lasted between 1 and 1.5 h, with the longest interview lasting 3.5 h. Although the in-depth interviews provided extremely rich illustrations of climate change in Délne, the time-consuming method significantly limits generalizability of the findings as well as excluding certain voices from the community.

By drawing on ethnographic methods, such as participatory workshops and fieldwork [24] and following protocols for ethical research established by the Sahtú Renewable Resources Board, these interviews resulted in the further documentation of Dene oral histories as well as contemporary observations of variability and change around Great Bear Lake and the surrounding region. Each interview was audio recorded with the assistance of Michael Neyelle and/or Mandy Bayha, then transcribed and coded to identify themes related to climate change and fishing livelihoods. Interviewees who provided prior informed consent are quoted in this study. In cases where participants did not want their name associated with their words, “anonymous” has been inserted. Coding consisted of highlighting predominant themes and then comparing individual transcript themes to the total sample. The most significant themes and subthemes from the analysis are presented in this paper; narratives are braided together with insights from the literature.

## 3. The Story of Délne Got’ine on Fishing Livelihoods

Long time ago, about 1946–1947, around that time, all the people depended on fish. Sometimes there’s caribou and sometimes there’s moose. And the way that people survived here was they shared whatever they [got]. And in regards to fishing, you fish all season and, in the winter—if you set a net, sometimes you can leave the net for two nights. And after two nights, you check it, you catch lots of fish and most of them are still alive. Quote from Alphonze Takazo—26 June 2017.

### 3.1. Why Is Fishing Important?

Fishing has always been critically important to the survival of the Sahtú Got’ine people on Great Bear Lake. In an early report that documents this substantial dependence on fish, fish were considered to be very nutritionally and culturally important for the Délne diet, along with other staple country foods such as caribou, moose, and geese. The major distinguishing factor between fish/fishing and

other traditional country foods is that fish are moderately accessible and available throughout the year, whereas other wild game are not always obtainable and require much more rigorous planning and efforts to execute a successful hunt.

Délne residents consistently expressed their pride at having the world's biggest lake trout, and an abundance of these populations in the lake. When discussing the importance of fishing within Délne, elders and experts provided various reasons as to why it is so profoundly important. The following quotes discuss the main motivating factors that explain why fish are a major food source:

It's extremely important because it's our primary diet. It's important to my family and community because its ... we live on GBL and that's what we eat a lot. The cost of food is expensive so ... it's free, good food ... When hunting was scarce we had fish ... Everything out there is free and it's the absolute best for me ... and it's just there for me but I have to work my ass off for it, but it's still free. And not just free, but the absolute best to put into my body ... But in the city, I don't have to work for anything. Everything is just there ... and it's not necessarily the best for me. Quote from Mandy Bayha—14 June 2017.

Food-wise ... fish was the main source of food, because back then the caribou didn't come ... So, we depended on fish a lot ... [it's] my life. Quote from Morris Neyelle—9 June 2017.

Fish [are] very important as [a] food source. Without fish, you won't have that—I forget what they call it—that oil that gives your life. And if you don't have that oil you will deteriorate. So, it's very important to have fish. Quote from Joe Dillon—15 June 2017.

For elders, they can't really depend on meat ... other meat. Fish is always ... has to be the number one food source ... She says that fishing is our number one livelihood. Because if you go, like, for hunting—for caribou or moose ... you have to go long ways. But for fish, it's just right here. You don't have to go too far, so that's why its number one now. Quote from Camilla Tutcho (as translated by Michael Neyelle)—19 June 2017.

One of the main follow-up questions concerning the importance of fishing was, “what would it mean to you if you could not fish anymore?” This question was asked in interviews where a certain rapport had been established, because asking this question could be seen as inviting that outcome. Upon reflection, after completing analyses of the results, it is advised that future projects that explore this type of inquiry should do so with extreme caution, because other communities undergoing this type of research in the future may not be as forgiving or understanding as the Sahtú Got'ine people. Responses varied, but typically they were followed by negative feelings that could be categorized as shock, dismay, or unhappiness. Most interviewees had never even thought to ask this question before because fish have always been abundantly available. The following quotes demonstrate how fishing is innately a part of Sahtú Got'ine identity, and to take away fishing would be to strip them of their culture and tradition.

That's just like saying 'don't do your tradition. Don't do your culture.' Because I've been taught that ... I've been taught fishing for a very long time. It provides food ... feeds a lot of people ... feeds the town people ... and if you just got what you need, I'm pretty sure you give fish to other people. Quote from Nihltla Bayha—22 June 2017.

Oh my god, I never even think of that! What would it mean to [me] if you couldn't go fishing anymore? May as well not even live here. Go live in the city. How sad is that? Quote from Verna Mae Firth—24 June 2017.

Sell my boat. I never think of that! Never even crossed my mind. Quote from Bruce Kenny—24 June 2017.

What would it mean to me? It would be devastation. Because fish is very important as the food source. Quote from Joe Dillon—15 June 2017.

While discussing the importance of fish and the lake itself, a subtheme of respect emerged. Interviewees always elaborated on practices and traditions that relate to how to respect GBL fish and how to keep the lake in its pristine condition for future generations. Most participants talked about how they continue to pick up after themselves in order to minimize garbage pollution in the lake. In terms of respecting the fish, interviewees discussed thanking the creator for their catch, and making sure humane harvesting methods were utilized. Lastly, it was related that some people do not catch fish over a specific weight because they are considered to be the ‘elder fish’ and are not to be consumed.

And making sure that we’re always clean. That we leave less of a footprint as possible . . . . And how we should be recycling a lot more, more mindful of the things that we are wasting . . . . I think for the most part a lot of people are aware and . . . making an effort to keep things as clean as possible. And I think Deline as a whole, are really mindful of that also because we have so much respect for the lake, like . . . that’s our freezer . . . that’s our food . . . that’s our food source, our life source . . . . Everything that we have to be healthy comes from our lake, so I think we’ve always been mindful of that relationship. And there’s even a saying that we say *sahtu keway*—‘Great Bear Lake is the boss.’ So, everything we do is surrounding GBL. So, we’re always mindful of how the lake is doing or how we’re interacting with the lake. Quote from Mandy Bayha—14 June 2017.

I usually catch fish . . . . I sometimes say like a little prayer saying thank you to the Creator. That’s the main thing the Elders always say is to pray for it, be thankful for what you get. Quote from Mitchell Naedzo—23 June 2017.

Well, what my dad tells me is that he would not eat [fish] over 25 pounds. He would never eat over 25 pounds . . . because . . . actually he just told me this yesterday. He said . . . its older than me and it’s a fish elder. Quote from Nihtla Bayha—22 June 2017.

### 3.2. What Are the Changes Seen in the Local Lakes and Rivers?

We wait like . . . for the river to break up, so . . . then we caught three [tubs full] . . . Anyways, just like for example with one net . . . I check it two nights . . . I check it four times and 160 [fish] altogether”. Quote from Anonymous—16 June 2017.

#### 3.2.1. Water Temperature

According to the literature, increasing water temperatures is one of the main driving forces causing changes in fish species abundance and distribution, which consequently also impacts species composition in marine ecosystems [25,26]. A lot of the completed research specifically covers oceanic temperature fluctuations and how these shifts lead to issues related to hypoxia and acidification, which has been widely documented to heavily influence marine and fish populations [27,28]. Much less research has been completed on freshwater sources and climate change; however, an article published in 1992 examines some of the predicted changes. According to Carpenter et al., climate change will impact freshwater sources through changes in river channel formation, vegetation composition, distribution of freshwater fishes, and hydraulic patterns [29]. Some of the changes stated in this article were also mentioned during interviews in Délne. Specifically, the revealed changes were varying water temperatures and levels, along with newfound variations in fish populations. There is a large consensus on how water temperatures are unquestionably increasing; however, there were mixed perceptions regarding changes in water quantities as well as what specific fish species and populations were responding to these changes.

In 1975, Lionel Johnson conducted a study that aimed to record certain characteristics about Great Bear Lake and one of the key characteristics documented was water temperatures around the lake [30].



According to his work, when the lake was covered by approximately 1.5–2.5 m of ice, the recorded winter temperature of the water 20 m below this ice was 0.06 °C. Furthermore, at the 200 m mark, the recorded temperature actually increases to 3.52 °C. Rouse et al. expanded on this research and recorded updated water temperature on Lionel Island (65.5° N, 122.0° W), a small landmass located in Great Bear Lake approximately 200 km east of Norman Wells and 60 km east of Déline [31]. Contrasting the 1975 Johnson findings, Rouse et al. revealed an increase in water temperatures at the 40 m depth mark, where temperatures ranged between 4.8 and 3.5 °C [31]. This particular project lasted two years and these documented recordings are the average temperature readings from that time period. When comparing the findings from Johnson [30] and Rouse et al., it is important to acknowledge that the conflicting recorded temperatures were taken at different water depths and the Rouse et al. findings are an average of yearly logged temperatures [31]. Additionally, GBL is considered to be a monomictic lake, meaning that the lake mixes water from top to bottom at one point during the year [30], which could also help explain the rather large temperature increase. More longitudinal research is needed in order to address this particular question and specific literature gap. Although there are some limitations to consider within the cited literature, this large temperature difference was observed and reiterated in Déline interviews amongst both elders and skilled fishermen specifically.

It keeps getting worse. And they did the water temperature—students came here, I don't know what year, seven or eight years' ago, and they said the water went up ... I think they said four degrees or something. Quote from Morris Neyelle—9 June 2017.

I think it makes a big impact—the temperature of the water. Like you can feel it. I notice like when you put your hands in the water, you can feel it; it's just warm. Usually you can't even put your hands in there for half a minute ... your hands get numb. In the summer time I notice, it's just warm. It's warm and then some days it's so warm you can just ... you know jump in the lake and just swim. Quote from Bruce Kenny—24 June 2017.

One of the major physical indicators that residents of Déline use to corroborate and validate their warming water perceptions is the quality of the fish meat. Residents indicate that the ideal fish flesh should be firm and vibrant in color, but due to warming water temperatures, the flesh is becoming softer, flakier and paler much faster than before. Subsequently, fishermen are having to check their net more often in order to obtain former established fish yields, as well as maintain previous standards of fish quality.

When you're cutting it up you can tell immediately ... like when the flesh is ... like the meat will fall apart against the blade ... that's the reason we have to check [the net] more often because if you don't, then a lot of your fish [are] not going to be super fresh ... because for some reason the temperature warming up you have to check [the net] more often than not. But you'll find if you don't check your net often then a lot of the fish will be like that. Just because they're like dead longer. And they don't keep in the temperature for some reason. Quote from Mandy Bayha—14 June 2017.

Like I've fished all my life—in the summer, especially in summer, having my net out there. And in 60s, going to 70s ... like my dad went out there and we check it. And each day, every second day we'd check—like we'd check today, tomorrow, the next day ... and we check it again, and it would be still fresh, the flesh would be hard, good for cleaning or making dried fish. But now, in 40 years' time, now I have to check it twice a day. But if I check it once a day, and I check it tomorrow, it will be mushy, like it's ... it's soft. Quote from Morris Neyelle—9 June 2017.

And in regards to fishing, you fish all season and ... in the winter, if you set a net, sometimes you can leave the net for two nights. And after two nights, you check it ... you catch lots

of fish and most of them are still alive. And he believes that is due to cold water. In those days, he says in the summer time, you could leave the net for two nights because the water's cold. But recently, the water is warming, he says ... So, you have to check the net every day. Quote from Alphonse Takazo (as translated by Michael Neyelle)—26 June 2017.

A fresh fish ... when you cut it open, you don't feel the soft or mushy kinda ... like its hard and slippery. When its mushy, it's like old—not when you catch them by hooks, but when they are caught by net ... they get spoiled fast though. Now they recommend you check your net twice a day ... once in the morning, once in the evening. Quote from Joe Dillon—15 June 2017.

### 3.2.2. Water Quantity

Fresh water is one of the most important resources in the world, especially for small northern Indigenous communities such as Délne. Since water has always been so abundant, residents of Délne have relied heavily on it for thousands of years for a multitude of reasons. Not only does Great Bear Lake provide fresh drinking water (except for known contaminated areas), it also provides a means of travel for hunting/trapping and for access to other communities in the winter and summer months. However, according to Schindler, a warming climate will adversely affect water quality and water quantity [32]. For Schindler, the question is not *if* climate change will create more perceptible water-related issues but a matter of *when*. He goes on to discuss how there is a niche need to properly document baseline information on many Canadian waters, including Great Bear Lake because it has “never been comprehensively studied” [32] (p. 25). Furthermore, Schindler discusses climate in relation to water quantity and how higher air temperatures are related to increased evaporation and lower water levels. This is a topic of discussion that was mentioned in interviews in Délne and how water levels have been dropping over the years.

She says, the water level use to be really high on Bear River. And one of the areas around Bear River, there's a huge rock ... boulder ... that's right in the middle, and those days you couldn't see that big boulder ... But since the 70s, when they boated over there, they could see the rock was beginning to show. And ... , now you can see it. Quote from Camilla Tutcho as translated by Michael Neyelle—19 June 2017.

I guess the water is low. The water level this time of the year ... this year is a little different. But our water levels ... I don't think we have the same level or the volumes of water that we had in Bear Lake. I think slowly ... this year especially, you can see ... Last year we probably had a foot, two [feet] at least. Normally the water would be up two feet. Oh yeah, all those rocks would be under ... well you see where the sand is right there, high water would be above there. But I think over the years the volume of water is not there in Bear Lake. You notice that because of the volume of water on the river as well ... its shallow. The way you used to go is not as deep anymore ... the normal travel routes have to change because the water level is not there. Quote from Walter Beazha—13 June 2017.

Although the dominant narrative expressed perceptions of lower water levels, there were still some people in the community who believed that the water levels were actually increasing or not changing whatsoever.

Higher water ... it's picking up the shores around here too. Like that beach down there used to be way bigger. Yeah and over here, those rocks ... you were able to sit on them, and now they're covered in water. I guess ice caps are melting, ... I'm not sure. Quote from Yata Yukon—28 June 2017.

Well I always put [my net] in the same spot, I catch a lot of fish there, so I just leave them ... Nothing's changed. The depth didn't change, the water didn't change. Quote from Anonymous—16 June 2017.



### 3.3. What Changes Have You Seen in Fish Populations in Recent Years?

Before we used to catch lots [of Ciscos] at the mouth of river ... now hardly any. How many times ... we set a net there, [we would catch] three, four hundred ... Now it's only a few.  
Quote from Chris Yukon—12 June 2017.

Climate change is not just about warming air temperatures; it is about worldwide ripple impacts, such as an accelerated retreat of mountain glaciers, reduced Arctic sea ice, and rising global sea levels. One of the other major consequences includes shifts that alter the frequency and intensity of climatic phenomena such as El Nino [33]. According to the literature, freshwater sources in Canada are already impacted by the cumulative effects of climate change. For example, in northwestern Ontario the mean annual air temperature of the Experimental Lakes Area rose by 2 °C and evaporation rates increased by 30% from 1960 to mid-1980 [34]. This temperature change has a huge impact on lake and fish dynamics because fish distribution is heavily influenced by climate at a regional scale [29,34,35].

According to the literature, the distribution of freshwater fish is influenced by many different factors operating at various different tiers [35]. At a regional scale, freshwater fish distributions in Canada are influenced by historical and environmental factors, whereas local-scale distributions are influenced by abiotic (e.g., water chemistry) and biotic (e.g., species interactions) factors [35]. For example, according to Pörtner and Peck, alteration in fish species composition may result as a direct effect of temperature on an individual species and this can lead to impacts at higher levels in the ecosystem [25] (p. 9). Johnson examines the distribution of fish species in Great Bear Lake and where they are normally found [30]. According to his research, there are two species of lake trout, (*Salvelinus namaycush*, and *Myoxocephalus quadricornis*) that tend to inhabit the lake at all depths and temperatures. Whitefish (*Coregonus clupeaformis*) are commonly found in bays and are usually caught in areas that are shallower than 20 m deep [30]. Three species are confined to the periphery of the lake—namely, walleye (*Stizostedion vitreum*), burbot (*Lota lota*) and the longnose sucker (*Catostomus catostomus*). Lastly, Johnson reports that the lake chub (*Couesius plumbeus*) and the trout-perch (*Percopsis omiscomaycus*), are present in the headwaters and in Great Bear River, but have not been able to fully establish in Great Bear Lake [30]. Since this research was completed in the mid-1970s, it was important to get a better idea of past and present fish populations, as well as how they may have changed over time. To better understand community perceptions regarding lake fish populations, participants were asked specifically how fish populations have or have not changed over their lifetime. There were a variety of opinions regarding this issue; however, there is a general understanding that certain fish populations have indeed declined.

Less Ciscos for sure ... there used to be lots. Quote from Chris Yukon—12 June 2017.

A long time ago she says she noticed too ... that ... way back in dog team days ... when they used to set nets for herring in the same area around ... they use to catch over thousands. And now it's no more than 30, maybe ... Quote from Camilla Tutcho (as translated by Michael Neyelle)—19 June 2017.

My dad took us out a lot on the land. So, I'd say yes ... netting and fishing ... Fishing on the cabin. We catch a lot of grayling ... You notice there's less grayling down the river.  
Quote from Yata Yukon—28 June 2017.

[George] noticed that the herring population has just about totally disappeared. He says just recently ... there's lower numbers of herring ... now there's less big [trout]. Quote from Michael Neyelle—20 June 2017.

None of the interviewees mentioned trout or whitefish as fish populations in decline. Contrastingly, some of the above quotes mention Cisco and how the population is declining but, according to Johnson, this species is considered an enigma because “they appear in some abundance in the bays of McTavish

Arm prior to breakup of the main lake, but are not caught in gill nets” [30] (p. 2000). Johnson does indicate that Fort Franklin community members have caught Cisco in the summer months; however, there are no in-depth interviews in the article asking these land users for their perspectives on the matter [30].

Similar to Cisco descriptions, community members mentioned that the grayling population is in noticeable decline. The literature states that this species is found in the greatest concentration in the Great Bear River [36] but, as the above community member has described, this is no longer the case. Lastly, community members mention the greatest decline in herring populations. In a different article written by Johnson, he mentions that herring are abundant in the spring and local community members eat it very regularly [37]. This earlier narrative completely contrasts current perspectives on herring populations, which further highlights the drastic changes that are currently occurring in Great Bear Lake. The interviews conducted in this study asked elders and fishermen their assessment of these important matters, because they have utilized lake and fish resources all of their life. These on-the-land observations are more valuable than a short two-year study (that only looks at species presence models) because they are longitudinal in nature, which allows the Sahtú Got’ine to detect abnormal environmental variability more accurately. What is even more interesting and important is that even the youth are starting to notice these significant changes within their lifetime. This intergenerational, longitudinal, on-the-land knowledge becomes key for understanding historical and current changes to the lake, fish, and lake ecology, and how to better maintain a sustainable future for the community.

According to the literature, freshwater biodiversity has declined faster than either terrestrial or marine biodiversity over the past 30 years [38]. Since northern communities rely heavily on country harvested foods to meet their nutritional needs, this increasing trend could cause a major shift—especially in fishing communities such as Délne. Fishing is so much more than just a daily activity; it is considered to be a deeply cultural and spiritual pursuit, and the knowledge associated with it is deeply rooted in Dene teachings and stories. Each fish species is critically important in their own way, and to completely lose an entire species would also mean to lose the stories and TEK associated with that particular fish. For example, Mandy Bayha shared an amazing example highlighting the importance of traditional fish stories; she discusses the story about an old lady who falls into a river with a pack of tools and how those tools look like the bones found in the fish head. They share this story to teach young children to be mindful of the small bones so that they don’t choke:

*You sit there and be mindful of the bones ... “Oh, see you can find the axe ... oh see if you can find the knife ... how many tools can you find?” so, as a child you are trying to make sure you get all the meat off the bones ... but being mindful of the bones and making sure not to eat them.’*

This particular Dene story further demonstrates how TEK is immensely important for sharing specific information across generations, and emphasizes the significance of connecting with the environment and understanding fish complexities. To lose these kinds of stories would mean losing their identity, because the Sahtú Got’ine of Délne are intricately shaped by the fishing environment that surrounds their community. The importance of fish is clearly not just for its nutritional value, and therefore climate mitigation strategies should reflect this reality. The narratives originating from this thesis should be evaluated for more than just scientific information; they should also be used to guide community-based strategies that reflect community objectives and incorporate traditional methodologies into policy.

### 3.4. What Changes Are People Noticing in the Winter?

Like when I was young I used to play and the snow drifts were way bigger than I was. And we used to play on those all the time ... like it was the best time of my life ... we used to snowmobile ... on the snow drifts—like we were kind of crazy. But now ... I mean like last year, it’s not like that anymore ... I think last year we didn’t really get too much snow.

I was here in, like, December, and I could still see the willows . . . like some of the willows sticking out where usually its completely covered. Quote from Mandy Bayha—14 June 2017.

#### 3.4.1. Winter Temperature

In general, one key feature that characterizes northern Canada is its cold and frigid temperatures. For example, the coldest wind chill on record occurred at Kugaaruk (Pelly Bay), Nunavut on January 13, 1975, where the air temperature was  $-51^{\circ}\text{C}$ ; but with the wind chill, it was  $-78^{\circ}\text{C}$  [39]. Although Kuggaruk is much farther north than Délne, the community still experiences bitterly cold subzero winter temperatures. One key factor in Délne's climate is its location on Great Bear Lake, because large lakes have a considerable amount of influence on local and regional climates [40]. According to Auld and Kershaw, the climate in the Sahtú is also influenced by solar radiation from the Earth's surface and atmosphere. The heat from the sun is distributed by air circulation, and in the winter the Sahtú is dominated by air flowing from the polar region. In general, the Sahtú experiences long, cold winters, where the average temperature in January is between  $-20$  and  $-30^{\circ}\text{C}$  [40]. While discussing some of the seasonal environmental changes observed around Délne, many participants mentioned specific changes related to temperature in the winter season.

He says a long time ago it was really cold—it was very, very cold compared to today . . . he's talking about 40, 30 degrees. Today it's more than 20 or something . . . So, it's sort of warmer winters. In the past, he says they're always out on the land . . . and even on the land, it gets really cold . . . even the trees would explode . . . tear right apart. And the dogs would cry. Quote from (Alphonse Takazo (as translated by Michael Neyelle)—26 June 2017.

But the main part of the lake used to be cold all the time . . . we used to wear parkas but now we don't do that anymore . . . we don't have -40 weather anymore. You can check with the weather people but I don't think we did. Imagine that. Last year our average temperature was higher than Winnipeg . . . in the average in December. Quote from Walter Beazha—13 June 2017.

The overall consensus from the interviews is that winter temperatures are definitely rising and these changes are becoming more noticeable. The next section discusses the key indicators that community members use to show that the winter season is significantly changing.

#### 3.4.2. Ice and the Winter Road

Winter in Délne is a very important time of year, since it is the longest season but also because of the winter road, which allows access to the outside world. In order for the winter road to be considered safe enough to open, the ice must reach a certain thickness so that large commercial and residential trucks can drive across the lake. Not only does the winter road allow access to other communities, it also provides improved access to resources (such as a greater variety of food at the Northern Store or Co-op), as well as cheaper access to Yellowknife services that would normally only be accessible by aircraft. However, since the winters are becoming warmer, the ice road is taking longer to freeze and the ice on the lake is tending to be thinner than before. Interview participants discussed late freeze up as well as how the ice itself is becoming slushy and wet rather than solid.

And here, the ice is not as thick as it used to be. [It used to be] six feet plus. And he says sometimes it rains in the winter. That never used to happen. The one time it happens in like maybe April or May. Quote from Alphonse Takazo (as translated by Michael Neyelle)—26 June 2017.

Well, when we were kids too, the ice used to be really thick. Now you're lucky if you hit five feet . . . And the lake . . . it takes longer to freeze. Like 5, 10 years ago I would cross in the middle of November, but now sometimes you won't even cross in December . . . the lake. Quote from Chris Yukon—12 June 2017.

Because it's getting warmer ... But one of the things I find now is when it starts freezing, it will take a long time to freeze, so it creates this slush all over. And that's what freezes ... It creates all these bubbles ... So when spring time comes, it just goes fast. Quote from Morris Neyelle—9 June 2017.

Another iconic indicator that people referred to was when a fuel tanker fell through the ice road. According to the CBC website, the incident occurred on March 5, 2016 and the tanker was halfway submerged approximately five kilometres from the community [41,42]. This is drastically significant because, according to the Northwest Territories government website (under the 'Winter Roads' heading), the Délne winter road is normally open until March 30 and this approval is based on a 15 years average [43]. This information is based on long-term averages; however, it is clear that the environment is changing faster than people realize, and decision makers should be including community perspectives when defining winter road safety regulations.

To most Canadians, warming winter temperatures would not be considered a significant problem. However, for isolated northern communities that are only accessible by winter road, cold winters are greatly appreciated. Warming winter temperatures not only bring shorter winter road seasons and less access to necessary outside resources, they also present major safety concerns with regard to on-the-land activities and travel. Some people in Délne continue to set nets in the winter months, and although it is a very rigorous task, the payoff is considered to be worthwhile. The TEK providing the ability to read the ice is absolutely essential when setting a winter net. If one is unable to read or predict the ice properly, it could result in tragedy or loss.

A lot of community members also talked about their cabins around Great Bear Lake and the skidoos they use to gain access to these cabins. These pieces of equipment are heavy, and if the ice is becoming thinner every year, it is only a matter of time until one accidentally falls through the ice. The ability to accurately predict ice thickness throughout the winter months has provided confidence and security for Délne residents. However, as the ice becomes more unpredictable, confidence could be replaced with fear or anxiety, resulting in a decline in on-the-land travel. Maintaining this level of confidence is extremely important for the future of Délne, because preserving traditional activities and youth participation in these activities is a major concern. There is significant cultural stake associated with maintaining traditional winter practices. The overall well-being of future generations relies heavily on the ability to set net in the winter and/or to safely travel to the family cabin. The rapidly thinning ice is something that community members have not encountered in the past and they should be taking the above perceptions into consideration when devising possible solutions. By doing so, policy can reflect community perspectives more accurately, and better achieve a solution that respects the environment at the same time as the relationships residents continue to maintain with their environment.

### 3.5. *What Changes Are Being Observed in Fish Health?*

Deer Pass Bay ... one time we were there in the fall time ... there was hardly [any eggs in there]—usually they spawn there in the fall time, but not that much ... . We checked a few, but some of them just [are] thin ... not ready to lay eggs. So just maybe [this year I got about thirty] fish ... Maybe five or seven ... all it has eggs like this. Quote from Anonymous—16 June 2017.

Fish and fishing are a source of pride for many individuals in Délne; there is a lot of dialogue around how people from all over the world come to Great Bear Lake on the off chance that they will catch one of their world-famous fish. As previously mentioned, Great Bear Lake fish are considered to be extremely important for nutritional and cultural reasons, which is why maintaining the pristine health of the fish is so important. Community members continually mention how important it is to take care of the lake for future generations so that the much-needed resources can continue to feed the community. However, one of the topics of discussion that arose from interview conversations was the increase in visible cysts found on the fish. Perceptions varied in what causes this issue and whether

the fish were still satisfactory to eat, but there was a large consensus that the overall health of the fish is definitely changing in Great Bear Lake.

My dad just told me this ... cysts. If there's no cysts in the fish then it's really healthy.  
Quote from Anonymous—16 June 2017.

In the last few years, I've noticed a lot of cysts in the Ciscos ... And I've noticed in the last maybe 5 years ... cysts in trout. I've never really seen them in trout before ... maybe one fish ... or two fish or something that I've seen with the cysts. But before that ... I've never really seen them before. But the Ciscos ... there's definitely [cysts], its normal sometimes that you would expect out of a bunch of fish that you are cutting up that at least a good percentage of them would have one or two cysts or something. Quote from Mandy Bayha—14 June 2017.

Well I did once ... We squeezed it out and cut it off ... We didn't throw it back. The cysts that you can see are inside the fish, you can't see them outside of the fish. That's what I'm saying.  
Quote from Nihltla Beazha—22 June 2017.

He says sometimes when you cut fish open, you look at the meat. The meat sometimes you'll see some white stuff on it. If you see that, you're not supposed to eat it ... the whole fish.  
Quote from Alphonse Takazo (as translated by Michael Neyelle)—26 June 2017.

But she says just recently George Dolphus ... he set a net for herring and he caught lots of herring. And gave some to Cam to make dry fish ... and when she works on making dry fish ... she has to throw away at least 10 or more, of these little herrings. Quote from Camilla Tutcho (as translated by Michael Neyelle)—19 June 2017.

Try and spell that ... batayhalah (parasite) ... George says that some of the fish they have it ... it's like a puss. Cysts ... he's looking for fish without those ... those cysts. They're not ... a really health problem. You can cut it out. You can cut it out and it's still good.  
Quote from George Kenny (as translated by Michael Neyelle)—15 June 2017.

In an early fish study concerning observations specific to the trout in Great Bear Lake, the authors mention the presence of parasites and cysts. According to Miller and Kennedy [43], a specific species of tapeworm (*Triaenophorus crassus*) was commonly found in the intestines and muscles of trout. This particular tapeworm is an important parasite in GBL trout because it occurs in plerocercoid (larval) form, encysted in the muscles chiefly between the head and dorsal fin [43] (p. 187). Miller and Kennedy's detailed analysis highlights that cyst occurrence is light in most locations, but severe in Conjuror Bay, and is also considered to be fairly severe in the Richardson Islands area. It was also noted that approximately one-third of the fingerling lake trout in Bear River had one or two conspicuous bulges on their backs that interfered very noticeably with swimming [43]. According to Lawler and Scott, the known range of this particular genus of tapeworm lies between "42° N latitude (Indiana, U.S.A.), northward to 67° N latitude (Great Bear Lake, Northwest Territories, Canada), and from the lower St. Lawrence River northwesterly to Alaska" [44] (p. 890). In the same year, Meyer states that these cysts are harmless to man but are objectionable in appearance, which renders the infected fish unmarketable [45].

#### 4. Discussion and Conclusions

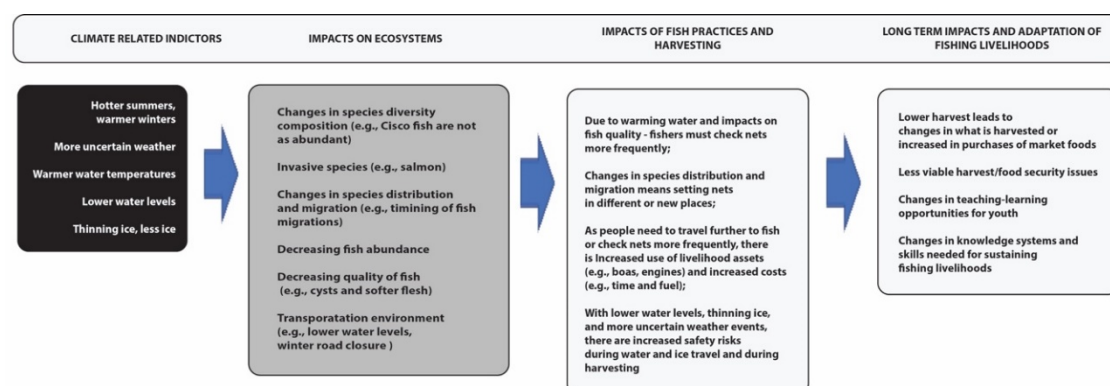
Climate change is increasing stress on both fishing and fishing livelihoods across the Canadian northern regions. Much of the literature related to northern ecosystems has highlighted the value of traditional knowledge in arctic regions and elsewhere in illuminating new climatic trends and patterns as well as its contribution to the capacity of individuals and institutions to cope and adapt [46–48]. While there is less specific research related to fisheries and subarctic regions of Canada, work carried out



in Alaska, Greenland and Scandinavia suggests traditional knowledge is also critical in this geographic and livelihood context [49–51].

Through this study, we have contributed to this growing literature by learning from Sahtú Got'ine fishers about their experience of climate change and its impact on their fishing livelihoods in the Great Bear Lake region of the Northwest Territories. This work highlights some very specific ecological changes and their socioeconomic, cultural and health impacts (Figure 2). For example, due to increasing water temperatures causing the fish flesh to soften, people are having to check their net more frequently (twice per day), which is drastically different from what elders described to be the historical norm of once a day. This increase in net inspection frequency requires an increase in fishing expenses, such as fuel, and increased maintenance for boats, engines and nets. Related to this issue of warming water temperatures is changes in winter weather, and therefore the lake ice. Fishers also discussed the decline in fish populations and increase in fish health-related observations (e.g., cysts). There are questions among fisheries about the risks of consuming fish that have cysts, but when coupled with declining populations and softer flesh, previously viable fish harvests become extremely vulnerable to sharp declines. There are also increased risks during winter due to warming temperatures and thinning and unpredictable ice conditions on the winter road could add to overall shipping costs—or in an extreme instance, suspend trucking services altogether. Lastly, community anxieties around falling through the ice could eventually peak, which could potentially prevent future generations from traveling on the land during the winter season. These new perceptions and experiences around current water and ice patterns could become the new standard of TEK, which attests to its resilience and adaptability, but also suggests that new knowledge will be passed down to future generations, marking the potential for lost knowledge concerning the old ways of living.

These changes result in stress on food security; as fishing becomes more risky and the abundance of fish declines, people may become more heavily dependent on market foods which are less healthy and more expensive. There are other costs as well. Like many other northern Indigenous groups, the Sahtú Got'ine place a certain cultural, symbolic and spiritual value on country foods that cannot simply be reassigned to industrial foods [46,47]. In addition to a shift in dietary customs, increased incurred costs could push more people toward paid employment and away from traditional fishing activities. Since cultural continuity has been extremely important for developing Indigenous identity and overall well-being [48–52], it is critically important that the Sahtú Got'ine continue to practice sustainable fishing methodologies so that future generations can maintain a deep understanding about what it means to be a Dene. This is not to say that the community will stop fishing altogether, because it is inherently part of who they are, but it raises awareness that financial drivers may start to have a larger impact on lifestyle choices.



**Figure 2.** Climate change in the Sahtú—impacts and pathways. Inspired by Badjeck et al. [53].



Climate change is among the most significant problems facing the world's Indigenous peoples [54]. This becomes most obvious when we look at the increasing amount of research concerning its impacts on natural and social systems, especially, for example, northern Indigenous peoples.

However, these impacts cannot simply be looked at a macro level. Many of the climate-related challenges that Canada faces are region specific, and each distinct area will require adaptive management approaches [55]. Although some management and mitigating strategies have already been devised for western Canada [56,57], these policies are species specific and would require various changes in order to be appropriately implemented in northern Canada. However, Poesch et al. also state that “our limited knowledge about the biology of Arctic fishes and their ecosystems, combined with uncertainty regarding the specifics of climate projections, limits our ability to prepare for the predicted changes” [55] (p. 390). In order to help potentially solve this issue, the authors make five recommendations that could advance research outcomes and improve management strategies. In accordance with the second recommendation, this paper also suggests that it would be best for research to take an ecosystem-based approach to management of climate-related threats at local scales in order to improve community-based solutions that accomplish both research and community outcomes. An ecosystem approach is needed that accounts for the social dimensions of climate change including impacts on the livelihoods for fishers [58]. By networking and operating in conjunction with northern communities, not only can respectful relationships be created, they can also begin to accomplish the collective goal of the sustainability of GBL fish and the continued maintenance of traditional fishing practices in Délı̄ne.

This study looked at how climate change is beginning to affect fish and fishing livelihoods in Délı̄ne—a small community located in the Northwest Territories. Participants claimed that there are a variety of changes occurring in and around their community, the most noticeable included higher water temperatures, declining water levels, and an observable decline in certain fish populations, ice thickness, and overall fish health. The subsequent impacts of these climate-related changes include softening fish flesh, less viable harvests, composition changes for specific fish species, and safety concerns. The adaptation strategies that community members are choosing to employ include checking nets more frequently, setting fish nets in new places (which subsequently changes TK for future generations), as well as cutting out cysts from fish flesh. These changes are not going to stop the community from continuing to fish because fishing is an innate part of who they are. The Sahtú Got'ine will continue to adapt to their changing environment and demonstrate their resilience and the cultural significance that GBL has for the community.

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