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Climate change and community fisheries in the Arctic: A case study from Pangnirtung, Canada

Abstract: Coastal fishery systems in the Arctic are undergoing rapid change. This paper examines the ways in which Inuit fishers experience and respond to such change, using a case study from Pangnirtung, Canada. The work is based on over two years of fieldwork, during which semi-structured interviews (n=62), focus group discussions (n=6, 31 participants) and key informant interviews (n=25) were conducted. The changes that most Inuit fishers experience are: changes in sea-ice conditions, Inuit people themselves, the landscape and the seascape, fish-related changes, and changes in weather conditions, markets and fish selling prices. Inuit fishers respond to change individually as well as collectively. Fishers' responses were examined using the characteristics of a resilience-based conceptual framework focusing on place, human agency, collective action and collaboration, institutions, indigenous and local knowledge systems, and learning. Based on results, this paper identified three community-level adaptive strategies, which are diversification, technology use and fisheries governance that employs a co-management approach. Further, this work recognised four place-specific attributes that can shape community adaptations, which are Inuit worldviews, Inuit-owned institutions, a culture of sharing and collaborating, and indigenous and local knowledge systems. An examination of the ways in which Inuit fishers experience and respond to change is essential to better understand adaptations to climate change. This study delivers new insights to communities, scientists, and policymakers to work together to foster community adaptation.

Keywords: Adaptation, Climate change, Inuit, Arctic, Fisheries, Learning, Resilience

1. Introduction

Inuit communities in northern Canada are undergoing profound changes, in part because of changing climatic conditions (Arctic Council, 2016, AMAP, 2018, Ford et al., 2019). The region warmed by 1.6°C during the period 1948-2014, a rate at least twice the global average; this has been accompanied by a loss of sea-ice, reduced snow cover, a loss of lake/river ice, permafrost degradation, warmer seas that hasten the melting of glaciers and ice sheets, and species shifts (Duerden, 2004, Ford, 2009b, Ford, 2009a, Ford and Beaumier, 2011, Ford et al., 2013, Ford, 2014, Ford et al., 2015a, Arctic Council, 2016, Clark et al., 2016b, AMAP, 2018, Ford et al., 2018, Ford et al., 2019). These changes have had implications for fisheries, affecting fish availability, abundance and health, as well as access due to impacts on transportation networks. These changes present both risks and opportunities, the impacts of which will be determined not only by climate change, but also by social, cultural, and economic conditions and processes (Arctic-Council, 2013, Arctic Council, 2016, AMAP, 2018). Identifying ways to adapt, and thereby reduce the risks posed by climate change, as well as to take advantage of new opportunities, is emerging as a focus area in terms of decision making in northern Canada. Understanding how communities are experiencing and responding to the observed rapid change in climate is important for supporting such processes (Galappaththi et al., 2019).

While the empirical assessment of how communities adapt to change is an active area of research in the Arctic, limited work has been done in a fisheries context (with exceptions (2001, Ford et al.,

2006)). Those studies that do have a fisheries angle tend to focus only on subsistence-based fisheries as part of a suite of harvesting activities, such as hunting, trapping and traveling. Against this backdrop, here we assess community adaptations to climate change among Inuit fisher communities, using a case study from Pangnirtung, Baffin Island, Nunavut. The paper has two objectives: 1). to examine the ways in which Inuit fishers experience change, including climate change, and 2). to investigate the ways in which Inuit fishers respond to and adapt to such change. The study reveals various means by which Inuit fishers build resilience and minimise vulnerability (i.e. adapt) to the impacts of climate change. Finally, the paper identifies potential community adaptive strategies and key attributes that shape community adaptations in fisheries.

2. Methods

2.1 Study location

Pangnirtung is an Inuit community located on Baffin Island, in the Canadian territory of Nunavut, with a resident population of 1,481 (2016 census) (Figure 1). Pangnirtung Inuit have historically lived around the Cumberland Sound area in multiple settlements called 'outpost camps.' This is an isolated community accessible only by aircraft, and by boat during the summer for supplies. Travel in and out of the community is extremely expensive. Residents have to cope with unique challenges including high rates of food insecurity, housing shortages, and low rates of high school graduation, comparable to other small Nunavut settlements (Ruiz-Castell et al., 2015, Arctic Council, 2016, Collings et al., 2016, Huet et al., 2017). The community is a hotspot for climate change, with documented changes and impacts including changes in sea-ice conditions, severe weather conditions, permafrost thaw, emerging landscape hazards, and stresses to wildlife population dynamics. Pangnirtung is experiencing these changes more quickly and acutely than other places in the region, perhaps in part because of the popularity of the community for tourists, for whom Pangnirtung is the access place for visiting Auyuittuq national park (Egeland et al., 2009, Spinney, 2010, Diemer et al., 2011, Laidler et al., 2011, Short et al., 2011, Peacock et al., 2013, Moore et al., 2014, AMAP, 2018).

Pangnirtung is one of the few communities in Nunavut that has significant commercial and subsistence fisheries activity. A fish processing plant, Pang Fisheries Ltd., ('fish plant') located in the community is an Inuit-owned private entity operating since 1992. This fish plant serves two key fisheries, an Arctic char (Salvelinus alpinus) fishery and a turbot/halibut (Reinhardtius hippoglossoides) fishery. These are commercial and subsistence fisheries. Inuit have been more dependent on char as a food source for many generations and on turbot as a source of seasonal revenue. The fish plant exports about 90% of its turbot to East Asia (Japan, South Korea, Taiwan, China, and Vietnam), while the rest goes to Chinese communities in Canada, mainly in Toronto and Vancouver and the U.S. The market for Arctic char has shrunk since about 2008 and most of the Arctic char presently goes to buyers in Nunavut (for example, Iqaluit).

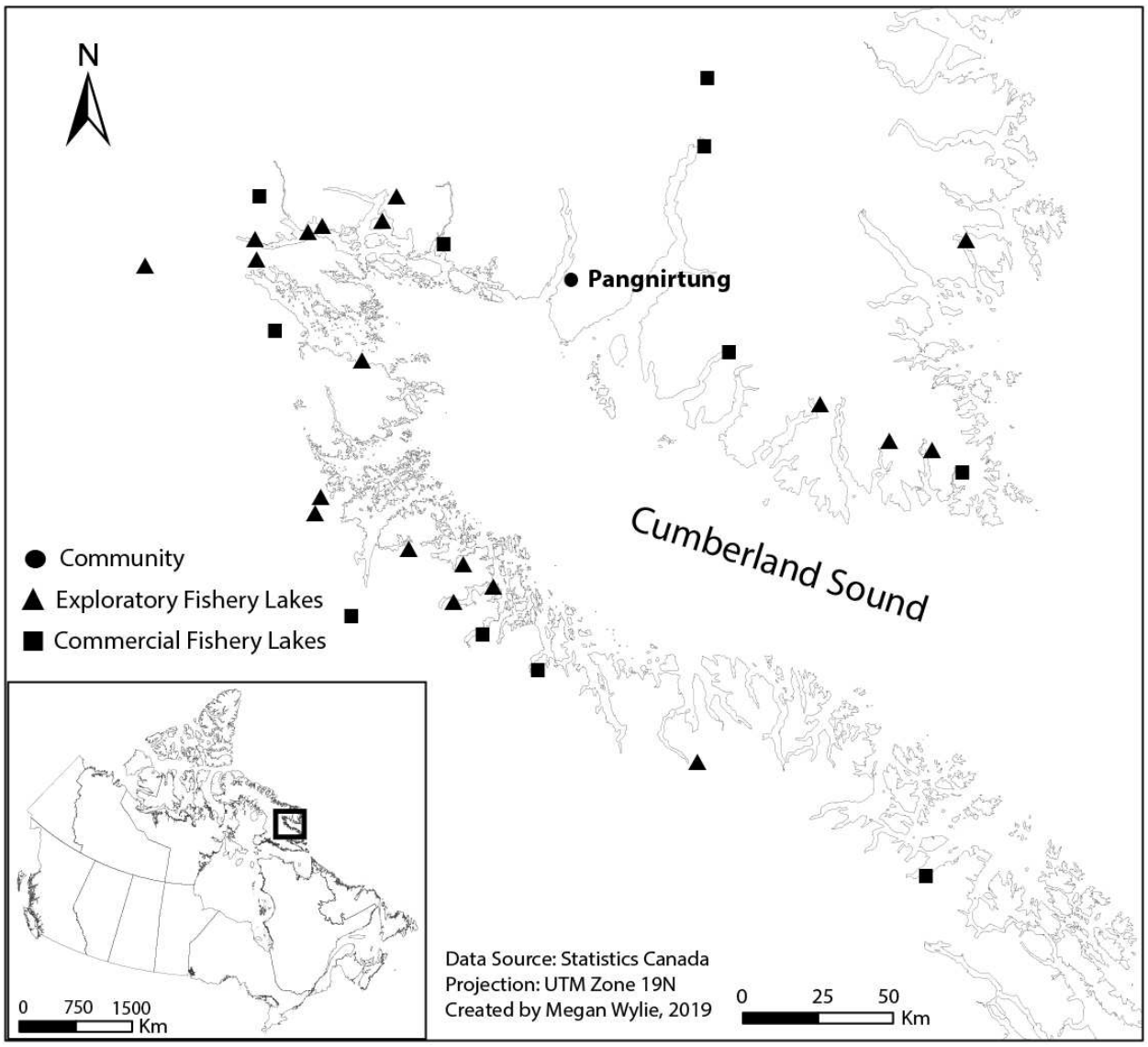

Figure 1: Location of the Pangnirtung (the community) and Cumberland Sound (water body) in Baffin Island, Canada. Pangnirtung Inuit use the surrounding lakes for winter Arctic char fishing for both exploratory and commercial purposes.

Pangnirtung Inuit have an intimate connection to the surrounding Cumberland Sound area for fishing and hunting, and a detailed knowledge of species (Idrobo and Berkes, 2012). Caribou, seals, and Arctic char are the most important food sources for the community (Figure 2). Several other seasonal resources, such as turbot, ptarmigan, eiders, polar bear, kelp, arctic hare, clams, and beluga, are also important to health, culture, and wellbeing. Inuit fishers/hunters go out 'on the land' and spend days outside the community. During the winter and spring turbot fishing seasons, fishers drive snowmobiles for about 50-100 km on the frozen ocean and spend several days on the sea-ice in the Cumberland Sound area.

Arctic char is an anadromous species, feeding in the sea and overwintering in lakes. During the winter, people travel on frozen inland lakes around the community for Arctic char fishing.

Fishing/hunting for local 'country food' is an essential part of Inuit culture and way of life. The community's two grocery stores (co-op and Northern store) provide some alternative food sources, yet Inuit still consider country food to be their main food source as opposed to the expensive, less nutritious processed food from the store. Thus, changes in country food availability can have a large impact on Inuit diet. The study area was a good caribou hunting ground before the caribou migrated to western Nunavut lands, resulting in an increased reliance on the ocean for food security (Poole et al., 2010, Le Corre et al., 2017) (Appendix-Box S1).

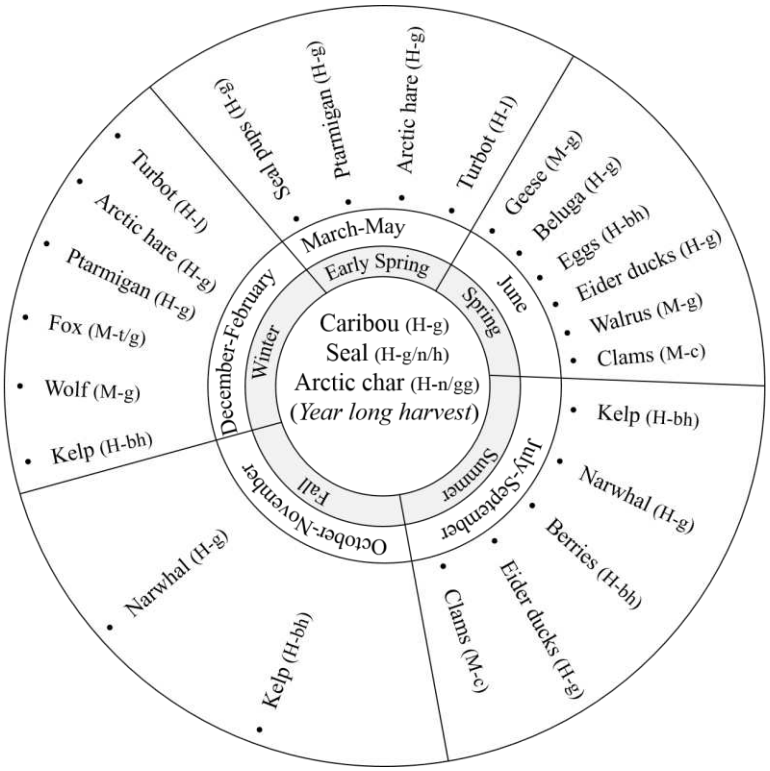

Figure 2: Seasonal food calendar for Pangnirtung (building on Egeland et al. (2009)).
Intensity of harvesting activity: High (H), Medium (M), Low (L). Hunting equipment: Gun (g), Gillnet/seal net (n), Traps (t), By-hand (bh), Long line (l), Collecting tool (c), Gigging (gg), Harpoon (h).

2.2 Conceptual approach

A social-ecological systems (SES) framing underpins our conceptual approach for understanding the nature of integrated Inuit and the Arctic sub-systems (Berkes et al., 1998, Berkes et al., 2003). The integrated social-ecological system (SES) is the unit of study. Economic systems and markets are not treated as separate but nested in the SES, allowing for an understanding of the complexities inherent to the Pangnirtung Inuit fishery -- a 'complex adaptive fishery system' (Mahon et al., 2008, Folke, 2016, Arlinghaus et al., 2017). Here we use the term 'fisheries systems' to refer to the coupled sub-systems of Pangnirtung Inuit and their land/water and associated socio-economic and cultural aspects related to fisheries activities.

This paper uses the characteristics of a resilience-based conceptual framework (2019) to identify and assess the adaptations of Pangnirtung Inuit towards stressors of the fisheries system. The framework has six characteristics used to create a better understanding of the SES change and of

the human responses to such change: place, human agency, collective action and collaboration, institutions, indigenous and local knowledge (ILK) systems, and learning (Table 1). This framework provides indicators that guide the assessment process, and the results are structured around the indicators under each framework characteristic. A conceptualisation of resilience as a function of coping, adapting, and transformative capacities (Béné et al., 2014, Brown, 2016) permits the capture of macro-level understanding of adaptation, with micro-level comprehensive details in fishing communities. This conceptual tool was developed based on an integration of the two scholarship areas of resilience thinking and development studies (Galappaththi et al., 2019). Use of this framework allows for the assessment of the process of community adaptation in Arctic fisheries systems, and for insights into adaptation needs and relevant policy.

Table 1: Definitions of characteristics of the resilience-based framework (Galappaththi et al., 2019).

Characteristic	Definition	Indicators
Place	Social and physical space that has attachment to Inuit. Attachment to place is understood as the bonding that occurs between people and their meaningful environments (livelihoods, culture, and wellbeing).	1) Number of species available for fishing. 2) Level of fishery resource availability. 3) Level of vulnerabilities for fishing operations such as climatic uncertainties. 4) Changes in livelihood activities relative to place (hunting/fishing). 5) Culture, including belief systems and perceptions that link to place.
Human agency	Inuit (individual or collective) capacity to act independently in making their own decisions as part of the process of the Inuit way of life.	1) Ownership of or access to fishing gear (boats, nets, engines). 2) Fishing gear diversity (number of different items of fishing gear used). 3) Occupational mobility (number of different fishing operations practiced). 4) Occupational multiplicity (total number of jobs in the household). 5) Access to credit (loans) and insurance. 6) Use of technological advancements.
Collective action and collaboration	Action taken together (or shared) by a group of two or more people to meet a common desired objective.	1) Sharing of fish. 2) Sharing of fishing gear. 3) Spreading of weather information. 4) Sharing of information related to fishing operations (fish prices, quotas, fishing techniques/management practices). 5) Social networks.
Institutions	Local organizations that facilitate collective action that meets local goals (for example, co-managed institutions).	1) The aim of institutions (for example, contribution to local fishing activities). 2) Ownership (communal, local/indigenous, private). 3) Decision-making power. 4) Existence of partnerships.
Indigenous and local knowledge systems	Co-evolving cumulative body of knowledge and practice (observations, experience, lessons, skills) related to Inuit fisheries systems (or a place) and handed down through generations by cultural transmission; reflects the Inuit cultural identity.	1) Application of such knowledge. 2) Co-production of knowledge (combining indigenous knowledge with other kinds of knowledge such as local knowledge and/or modern technical knowledge). 3) Weakening of local/indigenous/ traditional knowledge through the SES change.

Learning	Social learning, which itself refers to collective action and reflection that occurs among Inuit as they work to improve the management of human-environment interactions.	1) Extent of the practice of learning-by-doing in the fishing way of life. 2) Number of opportunities for learning. 3) Ways in which local philosophical worldviews are compatible with adaptive thinking.

2.3 Data collection methods

A community-based participatory research approach (Magee, 2013) was used to guide the research to ensure community engagement to shape knowledge production. The study continually received feedback from the community through the Pangnirtung municipality, key informants including elders, and research assistants (Appendix-Box S2). During the field data collection, the researcher relied on three language translators (Inuktitut-English) and four local research assistants. All field data was collected according to the McGill Research Ethics Board Certificate of Ethical Acceptability of Research Involving Humans (file number: 52-0617) and the Scientific Research License from the Nunavut Research Institute (file number: 02 015 18R-M).

To understand the ways in which Inuit fishers experience and respond to change, including climate change, a qualitative mixed-methods research design was utilized, including participant observations (PO), semi-structured interviews (SSI), key informant interviews (KII) and focus group discussions (FGD) (Berg, 2016, Laurier, 2016, Longhurst, 2016) (Appendix-Box S3). Through participation and observation of Inuit fisheries' way of life over 14 weeks of fieldwork, participant observations (PO) obtained contextual knowledge about the ways in which Inuit experience and respond to change. From May 2016 to February 2019, four research visits were made to the community. The field period featured an extensive amount of time spent with Inuit fishers in the form of attending community events and meetings, visiting local institutions, and making fishing trips (n=6) to Cumberland Sound to experience summer Arctic char fishing and winter turbot fishing. The researcher participated in and experienced most of the fishing activities to develop an understanding of the conditions that fishers confront.

Sixty-two face-to-face semi-structured interviews (SSI) (Longhurst, 2016) were conducted with Inuit fishers to document the changes being observed in the region, and identify and characterize how they are being responded to (Appendix-Table S1). A snowball sampling technique was used to select participants, beginning with multiple snowballs (4) to overcome the recruiting of all respondents from a very narrow circle of like-minded people. Participants were recruited until saturation, at which interviewees provided no new information (Bowen, 2008). Interviews were conducted, audio-recorded and transcribed in the community of Pangnirtung during May 2017-April 2018 (Appendix-Table S2). The SSI questioning focused on "change" in general so as not to bias answers and to keep interviews open-ended, focusing on what issues and changes that Inuit viewed as most important. SSI helped obtain richer insights about the 'place' and its meanings and attachments (Williams and Patterson, 2008, Kaján, 2014). All the interview questions related to 'change' referred to "about 30 years back" in fishers' lives in the geographical area of Pangnirtung and the surrounding Cumberland Sound area.

Twenty-five key informant interviews (KII) were conducted with individuals related to Inuit fisheries to examine areas of knowledge that were not accessible via PO and SSI, such as data related to the fish plant (for example, market portfolios), government institutions (for example, subsidy programs) and key people such as elders. The researcher conducted interviews with

representatives from the HTA Hunters and Trappers Association (n=4), the fish plant (n=3), DFO Department of Fisheries and Oceans (n=1), NWMB Nunavut Wildlife Management Board (n=1), the hamlet office (n=6), Nunavut territorial government agencies (n=6), the soup kitchen (n=1), the community weather station (n=1) and Baffin fisheries (n=2). Further, KII helped validate and create an understanding of the connection among data gathered using other methods.

Six focus group discussions (FGD) (Carey and Asbury, 2016) were carried out to build thematic areas related to changes that fishers experience, and the key ways in which fishers respond to such changes. Inuit fisher groups of four to eight individuals participated in the FGDs, organised during the latter stage of the data collection process. The first FGD (n=4) focused on the theme of 'changes in Pangnirtung fisheries' and discussed questions such as what change means to Inuit, how change can affect ways of life, and what the key changes are. The second (n=5) and third (n=8) FGDs were organised under the theme of 'how Pangnirtung adapt to change'. The discussions built on questions such as how Inuit are responding to change and the key areas of response. The fourth (n=4) and fifth (n=4) FGDs aimed at Arctic char and turbot fisheries, respectively. The final FGD (n=6) was organized to reengage with the community and disseminate/validate the results.

Qualitative interview data were translated into English (where required), transcribed, and then analysed using content analysis (Yow, 2014, Hancock and Algozzine, 2015, Berg, 2016, Clifford et al., 2016). Almost all analysis was completed by a single team member; however, multiple times throughout the project, the data analysis process was supplemented with feedback from community members. The key techniques used were 'manifest' and 'latent' content analysis supplemented with 'critical discourse analysis' (Fairclough, 2013, Van Dijk, 2015, Van Leeuwen, 2015) to develop themes and patterns related to the ways in which Inuit experience and respond to change. To express the original point of view of respondents, direct quotations are also used. We used exact phrases from respondents but removed irrelevant text from the quotes. Microsoft Excel 2013 was used to analyse interview data with the purpose of creating descriptive statistics such as percentages, mean and SD. Percentages were calculated based on the data frequency. Percentages in the text refer to the number of respondents from the immediately mentioned sub-sample who made that particular statement. Initially, the study recorded 32 types of change that Inuit fishers experienced. Of these, the six most recorded changes were selected (based on data frequency and intensity of experience) for further analysis. The results were supplemented with selected quotes (from SSI/KII) based on the latent content analysis. The linkages among the selected changes were identified using data from PO and SSI and validated through KII and FGD. Data related to the ways in which Inuit fishers respond to change was collected primarily through the PO (research diary, photos, and researcher's first-hand experience) and SSI data, supplemented with KII and FGD. Data were presented and analysed using the conceptual framework (Galappaththi et al., 2019).

3. Results

3.1 Experiencing Arctic change

Inuit fishers experience change in many ways, and this process of change is integrated into their way of life. Table 2 provides quotes that describe specific details about the ways in which change is experienced, its impacts, and previous studies documenting similar changes. Change in sea-ice conditions was the predominant theme discussed by participants. The other changes related to the

people themselves; the landscape and seascape; fish including Arctic char, turbot, and capelin (Mallotus villosus); the weather conditions; and fish selling prices and markets. These changes were among the most recorded changes and this knowledge will help answer key questions such as: What are the key stressors and shocks in the Arctic region? How do climate change impacts affect Inuit way of life? How can such changes relate to adaptation to climate change?

Table 2: Fishers' quotes describing how Arctic change is experienced (n=62).

Nature of change: "selected quotes from fishers"	Impacts	Previous studies
Sea-ice conditions: *"Fishing season get shorter each year. Ice break up faster now. Last year ice was weak … once we boat in December … so strange … no cold … ice doesn't break at right time."* *"Ice* conditions are different now. We have to be more *careful. We see more thin ice … black ice here and there."*	Shorter fishing season because sea-ice melts and breaks faster and new ice forms more slowly (85%). Safety concerns because sea-ice is thinner and weaker than it used to be (46%). Changes in sea-ice conditions are linked to changes in weather conditions and Inuit people.	(Nichols et al., 2004, Laidler et al., 2008, Laidler et al., 2009, Laidler et al., 2010, Screen and Simmonds, 2010)
Inuit people: *"Some people [Inuit] starting to act like strangers to each other, yet knowing they are related…"* *"Back then Inuit were healthier than now. Now they [Inuit] can easily get sick. …back then we [Inuit]* never had big bellies like now. There [Inuit] were more old people before we move here from outpost camps. Now few *old people [Inuit] in Pang."* *"Values of the people* [Inuit] are still the same as *back then."*	Weaker bonding among family members and community (38%). People are more money-oriented and reliant on the world outside the community (25%). Now people can easily get sick and have more health issues; back then Inuit were stronger (19%). Changers in people are linked to all other areas of change identified in this study.	(Condon, 1990, Charbonneau-Roberts et al., 2007, Lehti et al., 2009, Kral, 2012, Dowsley, 2015)
Landscape and seascape: *"…we live nearby the river and mountains up there … our view is moving, and I think our land is moving…"* *"…our river moves a lot last couple of years … maybe permafrost is gone."* *"During the spring we see more water than* before, glacier melting. After they melt we see more water *running all over the place."* *"Now ice moves in different directions, we are not used to that."*	Economic damage to infrastructure (house, bridge, winter trails) due to changes in river and mountain landscape (29%). Melting glaciers around the community can affect the community's aesthetic value (25%). Safety concerns related to fishing as sea-ice (masses) moves to different areas of Cumberland Sound during summer (8%). Changes in landscape and seascape are linked to changes in Inuit and weather conditions.	(Nelson et al., 2002, Ford and Smit, 2004, Ford et al., 2010)
Arctic char, turbot and capelin: *"Arctic char meat is white now. It's not red anymore, not sure why … most of them are smaller than back then…"* *"The[re] were no* capelin back then, it showed up lately*, now they are many … grandmother said that the reason for Arctic char flesh turning white."* *"Relatively less Arctic char when compare[d] to the* days we went camping back then (up to 30 years *ago)."*	Food security concerns are due to changes in char color and texture (83%). Most elders (74%) do not like to eat whiter and softer Arctic char; 33% of elders suspect that the reason for the whiter flesh is the emergence of capelin. The char moving patterns seem to have changed, as the time when char come in summer is later now (25%). Some Inuit believe char populations are lower (17%). Changes in fish are linked to weather/climate.	(Grebmeier et al., 2006, Harwood et al., 2015)

Weather conditions: *"Now summer comes more often."* *"I used to go [to] Iqaluit every year April. Now when* we Ski-Doo we hit rocks because of less snow in *April."* *"In January, people from other communities coming here and they [wear] 'Parka',* they are saying it is *warm here in Pang."* *"Now we got more warm winds and it breaks ice … air is so dry … we lost our shack last year, during the* fishing, wind *blew it."* *"We get unusually high wind now. Last year we got* 140km/hr. I found some plastic bags in sea while fishing, it can damage my motor. Wind can bring *plastic anywhere."*	Safety concerns are raised: a) extreme weather (storms, rain) and uncertainty (73%), b) more frequent extreme windy weather (55%), c) unusually warm weather that can affect fishing activities (45%). Sand and dust storm conditions during the summer due to extreme winds. Wind brings plastic and garbage items to the sea and surrounding mountains; fishers found plastic in the Cumberland Sound sea, which can damage boat motors. Changes in weather conditions are directly linked to all other identified changes, except for changes in markets and fish selling prices.	(Laidler et al., 2011, Giles et al., 2014)
Markets and fish selling prices: *"…back then turbot prices about $1.75/lb and now* about $1.20/lb. Arctic char is $2-3/lb and now about *$2/lb. …back then [1980-*90s] there were two fish *plants but now we have one. We don't have* option to *sell anywhere else."* *"In winter time, some fishers sell to Iqaluit via plane."* *"Char is more profitable for us (Inuit fishers)."*	Prices have dropped over the last 30 years and fishers have only one place to sell their catch (80%). Market for Arctic char has shrunk during the last five years partly because buyers such as US restaurants are getting supplies from fish farms. Changes in market and fish selling prices are linked to the changes in Inuit fishing and external global economy.	(Lange and Consortium, 2003, Campbell and Bergeron, 2012)

Note: Percentages were calculated based on the data frequency—the percentage of respondents who mentioned a particular change at least once.

3.2 Responding to Arctic change

This section examines the ways Pangnirtung Inuit respond to identified changes using the six characteristics of a resilience-based conceptual framework. Tables S3 and S4 in the appendix illustrate Inuit adaptive responses against the framework indicators and provide specific quotes that describe details about how Inuit adapt to Arctic change, respectively.

3.2.1 Place

Place-specific conditions such as unique weather and resources availability can influence community adaptive capacity and adaptation processes (Amundsen, 2015, Adger, 2016). Arctic char and turbot are co-existing fisheries systems in Pangnirtung that help people cope with change. Arctic char is the staple food in the community and a popular subsistence fish as in many other parts of the North. However, Pangnirtung also has a commercial fishery on Arctic char during the summer. Only a few (15 in 2017) commercial char licences are issued, selected through a lottery system managed by the HTA. During the summer when Pangnirtung fiord is clear of ice, fishers start boating into Cumberland Sound waters for char, using gill nets. During the winter and spring after the formation of strong sea-ice, fishers travel via snowmobile to surrounding lakes to fish Arctic char using a short stick and a line with bait (referred to as 'jigging').

Commercial turbot fishing is popular because it brings a relatively large amount of money into the community. It is carried out during the winter and spring. Strong and thick sea-ice is essential to starting winter turbot fishing, as it requires travelling to the Cumberland Sound sea-ice and spending longer hours (sometimes days) on the ice. Turbot fishers travel on the frozen ocean between multiple (1-4) turbot fishing spots (ice holes). This is a high-risk fishing operation due to continuous darkness, extreme cold (<-40°C with wind-chill), and the fact that the Greenland shark is a potential by-catch for turbot long-lines (Idrobo and Berkes, 2012). Nevertheless, more Inuit are becoming involved in turbot fishing each year due to its seasonal money-making potential.

The community fish plant processes fish nearly throughout the year. The plant processes Arctic char in both summer and winter. The catch data for each year varies and some of the records are not accessible. The turbot catch has been showing an increasing trend over the years (Figure 3). Turbot provides considerable employment in processing. The total spent on wages in Canadian dollars was 789,262 (2013); 846,488 (2014); and 842,369 (2017).

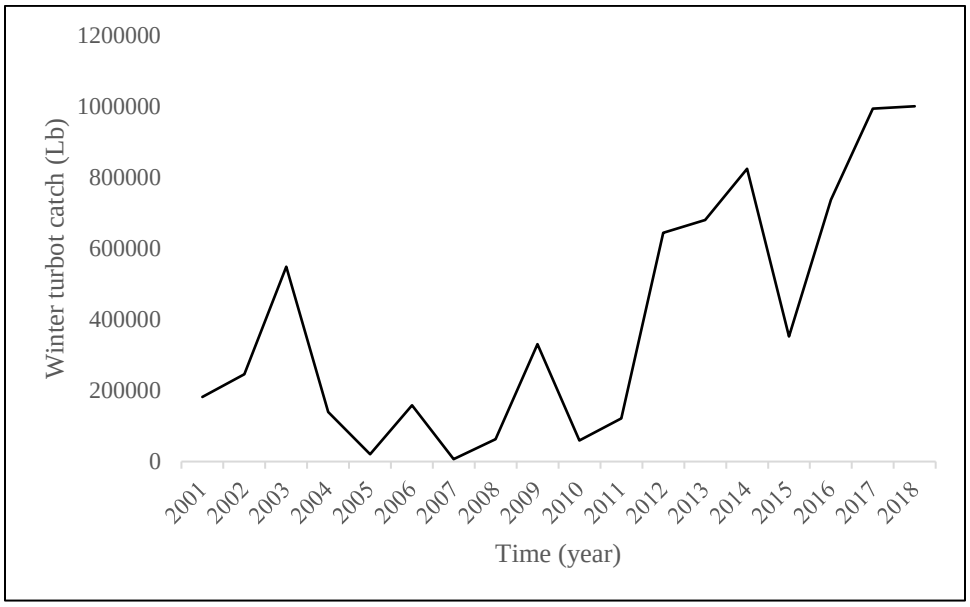

Figure 3: Growth in turbot fish catch.
Data source: The fish plant. (via KII)

Some 79% of respondents were involved in commercial fishing (Arctic char and/or turbot), 95% were involved in char fishing for subsistence purposes, while 15% engaged in commercial Arctic char fishing. Spending so much time on the land/sea for fishing and hunting shows Inuit attachment to, and reliance upon, their environment (or place). Sixty-nine percent of Inuit fishers indicated that no matter how much the environment and climate changed, they did not want to move away from Pangnirtung.

3.2.2 Human agency

Human agency is an essential component of assessing community adaptation as it relates to the adaptive capacity of the community's households (Cinner et al., 2015, Galappaththi et al., 2019).

A high level of human agency can indicate a high adaptive capacity to change (Cinner et al., 2015). We use four indicators of human agency to understand the adaptive capacities of fishers (Table 3).

Table 3: Indicators of human agency (n=62)

Indicators	Description	Mean	Standard deviation	How does it relate to adaptive capacity?
*Occupational multiplicity	Total number of jobs in the household.	0.7	0.8	Increases a range of income options available to cope with adverse conditions.
Access to assets	Access to number of assets required for fishing operations. Total of five assets: snowmobile; boat; fishing gear; qamutik (sled); truck.	3.8	1.1	Increases ability to go out to land/sea for adequate hunting and fishing that allows Inuit to earn more money and have required amount of food.
Fishing gear diversity	Number of different fishing gear used by each fisher. Total of six types of fishing gear: long line; gill net; jigging; fishing rod; clam digging tool; spear.	4.0	0.9	Increases the potential/ capacity to harvest range of country food options that help feed Inuit families.
Occupational mobility	Participation in the number of different kinds of fishing in the past year, total of four: char summer fishing; char winter fishing; turbot winter fishing; other fish.	2.6	0.5	Increases earning potential as well as fish harvest (for food), which improves buying power and food availability.

* Inuit have many other casual income-generating activities, such as selling seal skin, selling artwork, tourism-related activities, translating and research-related activities, and income support from the government.

Fishing constitutes a significant part of livelihoods in Pangnirtung, as 49% of fishers identified their occupation multiplicity as zero and most of fishers have less than one (0.7) total number of jobs in the household. Over 85% of fishers declared that they owned or had access to assets required for year-round fishing. Most (75%) had access to four to six types of fishing gear. Fishers have adopted technology such as Global Positioning Systems (GPSs) (56%), VHF radios (68%) and advanced rifles (19%) for fishing/hunting activities. Yet some (16%) prefer not to rely on technology, as they have limited access to service/repairs due to the community's isolated nature. Fishers have limited opportunities to obtain loans for the purchase of equipment such as snowmobiles and fishing gear, but they do have some access to credit/loans through Pang-Fisheries (13%) and Nunavut government (10%).

Some fishers were especially innovative. For instance, one fisher made a fly-proof food preserving box to save excess food (for example, Arctic char and beluga meat). Some fishers (11%) engaged in activities related to painting, craft work and carvings that bring extra income. Twenty-three percent of fishers save some money from turbot fishing to buy more long-lines or other equipment.

3.2.3 Collective action and collaboration

Collective action and collaboration can shape the community adaptation process by improving community cohesion and unity, which helps them cope with changes (Adger, 2003, Armitage, 2005, Pelling et al., 2008). This section examines collective action and collaboration, using qualitative indicators such as sharing of fish, fishing gear, information related to fishing operations, and use of social networks. Inuit fishers respond to change both individually and collectively.

Almost all fishers share their catch with relatives and elders, especially those who cannot fish and hunt themselves. Fishers and hunters (except those who support their families with food) often share, going on the radio and saying, "Look, I got a seal; come on over and help yourself." Thirty-four percent of fishers do not 'go public' and share with their extended family. The community offers organised food sharing events, while local institutions (for example, HTA, the soup kitchen) collaboratively facilitate such events.

Community members help each other mainly by communicating via local radio and internet-based social media, such as through the community Facebook page. For instance, they report vehicle or boat engine breakdowns, offer rides to the airport, share fishing equipment and offer to babysit so that the parents can go hunting/fishing. Thirty-nine percent of respondents share and/or are willing to share their hunting and fishing equipment (boat engine, sleds and snowmobiles). Hunting and fishing equipment is expensive, and 47% of fishers are reluctant to share due to previous experiences with lost or damaged equipment. People readily share weather-related information (for example, satellite images, wind conditions and storms) with fishers and hunters. However, three elders (5%) recalled that Inuit used to gather in the past before they went fishing or hunting; even at present Inuit have specific places where fishers meet before spreading out for winter seal hunting or turbot fishing.

3.2.4 Institutions

The engagement of local institutions with fishery resource management approaches and their effective collaborations with stakeholder institutions can minimize vulnerabilities related to the use of natural resources by enhancing the community's adaptive capacity. Here we unpack key institutions involved in collaborative decision-making related to fisheries.

Both the DFO (Department of Fisheries and Oceans) and the HTA (Hunters and Trappers Association), along with the NWMB (Nunavut Wildlife Management Board) and other designated Inuit organizations, are co-managers of the fisheries in Nunavut, as outlined in the Nunavut Agreement Article 5. Table 4 illustrates all co-management partner institutions that directly relate to the Pangnirtung fisheries co-management. Quotas are based on a combination of the best available science advice and traditional knowledge and must be approved by the NWMB and DFO.

Table 4: Key co-management institutions related to Pangnirtung co-existing fisheries.

Co-management partners	Aim/role	Ownership/ management approach	Decision-making
HTA	Co-manages fisheries with DFO and NWMB; selection of licence holders for char commercial fishery using a lottery system.	Inuit of Pangnirtung	Board of directors
DFO	Issues fishing licenses; monitors quotas; issues closer notices and monitors compliance concerns.	Federal government	Consultations (public, HTA, and other co-management partners)
NWMB	Co-manages fisheries with DFO and HTA.	NU territorial government	Board of directors
GN (Government of Nunavut)	Focuses on economic development and funding aspects for fishers and fisheries activities.	NU territorial government	Board of directors

RWO (Regional Wildlife Organization)	Overlooks harvesting practices of HTA and represents 'Inuit rights.'	Article 5 of the Nunavut Land Claim Agreement	Board of directors
NTI (Nunavut Tunngavik Incorporated)	Advocates and makes decisions as Inuit stakeholder. Represents 'Inuit rights.'	Article 5 of the Nunavut Land Claim Agreement	Board of directors
Fish plant	Buys fish and provides seasonal job opportunities in processing and shipping. Contributes to community events and supports Pang soup kitchen.	Private --100% Inuit owned	Board of directors

Note: See Appendix-Figure S1 for the co-management structure for Pangnirtung Arctic char and turbot fisheries (building on (Armitage et al., 2009)).

3.2.5 Indigenous and local knowledge (ILK) systems

ILK systems are recognised as a source of resilience, as well as a means of measuring the understanding of adaptations, as they underpin adaptive capacity to deal with change (Folke et al., 2003, Galappaththi et al., 2018, Galappaththi et al., 2019). This section describes applications of ILK, the combining of different kinds of knowledge, and the possible weakening of ILK through the process of change. Pangnirtung Inuit possess various kinds of knowledge accumulating and evolving over the generations (Idrobo and Berkes, 2012) , and shared among friends and peer groups. This knowledge is essential for harvesting, as well as adapting to environment and climate change (Berkes and Jolly, 2001). For example, it includes survival skills on ice, knowledge of Arctic char, turbot fishing techniques, and fish processing and marketing. Table 5 illustrates selected types of knowledge that turbot and Arctic char fishers use.

Table 5: Types of knowledge adopted by Inuit fishers.

Type of knowledge	Description
Place specific knowledge of Arctic char	-Arctic char migration patterns; knowledge of overwintering lakes. -Knowledge of fishing techniques and good fishing spots in the Cumberland Sound. .
Turbot fishing techniques	-The Pangnirtung Inuit learned turbot fishing techniques from the Greenland Inuit during the mid-1980s. -This knowledge continues to evolve from generation to generation.
Turbot fish processing and marketing knowledge	-Inuit owned fish plant holds much of the processing, selling, and marketing-related knowledge. -'fish plant' informed Inuit fishers about on-ice post-harvest practices.
Local environmental knowledge	-Fishing in high-risk conditions such as extreme cold, darkness, and Greenland shark that comes up as a long-line by-catch. -Knowledge about weather changes, tides, and water currents. -Knowledge about Cumberland Sound fish species.
Co-produced knowledge	-By working together and sharing and learning from each other, and working together with DFO and HTA, fishers combine and co-produce new knowledge.

Note: This knowledge information is derived from PO and FGD.

Focus group discussions highlighted the fact that some kinds of Inuit knowledge are getting weaker. In particular, young Inuit have poor knowledge of practices such as survival skills on ice, reading the sky, sewing seal skin and handling dog teams. Many elders possess such knowledge but have not necessarily done it themselves:

> I have watched my mother do it. They were basically teaching from what they remembered, not from what they did. We have lost teachers who know how to do [things]. We have teachers who know about the past, but even that generation is aging quickly. -- Elder (KII)

Thus, the weakening of traditional knowledge is an important influence on the way in which Inuit respond to present-day changes such as climate change (Pearce et al., 2015, Ford et al., 2016). On the other hand, young Inuit are taking advantage of technology and technical know-how to elaborate new knowledge and skills, such as using satellite images, drones to discover ice conditions, and underwater cameras to determine where the fish are.

3.2.6 Learning

Social learning is a key characteristic of community adaptation (Galappaththi et al., 2019). This section describes the extent to which Inuit practice learning-by-doing in their fishing way of life, the number of opportunities available for learning, and the ways in which local worldviews are compatible with adaptive thinking that supports the local adaptation process. Inuit fishers have various opportunities to learn about and adapt to change. During individual interviews, a large majority (84%) identified learning from elders and/or extended family members as a key means of learning about fishing. Thirteen percent of the respondents identified learning-by-doing while practicing fishing operations as a key means of learning. Apart from their first-hand experience, fishers communicate in close networks with friends and relatives, and incorporate their experience. During all the turbot fishing trips in which the researcher participated, fishers met and talked with other fishers on the way to their own "fishing hole". During focus group discussions, Inuit fishers agreed that both learning from elders as young Inuit and learning-by-doing are equally critical for adaptation to change.

Young Inuit are inspired by technology and readily utilize it. The elders say, "Now we need young people to teach us." Internet and school education are the means by which Inuit learn. When the researcher asked one Inuit fisher about Inuit turbot fish recipes, he replied, "Google it," with a smile. Only 29% of fishers have access to the internet at home and/or on their mobile devices. The remainder (71%) do not have access mainly because: a) they are not familiar with the internet (48%), b) it is too expensive (43%) or c) they are not aware of the internet (9%). In terms of education levels, 30% of fishers did not reach the junior high school level. Thirty-nine percent attended junior high; 19 percent reached the senior high level, but only 8% of fishers graduated from high school, and a further 2% have a community college diploma.

4. Discussion

This paper assesses how Pangnirtung Inuit experience and respond to change in a fisheries context. Climate change was identified as the most prominent change, and is perceived as being a real phenomenon by Inuit fishers and occurring in an unprecedented way (Ford et al., 2015b, Ford et al., 2019). The study illustrates six key items of change (i.e., stressors and shocks) related to: sea-ice conditions, Inuit people, the landscape and sea scape, fish, weather conditions, and markets and fish selling prices. The major ways in which fishers experience change can be characterized as: (a) the Arctic SES is being impacted by multiple stressors simultaneously; (b) climate change

has mixed/interconnected implications for Inuit fishing way of life; (c) Inuit themselves are changing over time due to the Arctic SES change; (d) many of the changes related to climate change are clearly noticeable in the Arctic; and (e) changes related to the market economy (fishing industry) mean that Inuit have to rely on outside economies. Table 6 explores the implications of change experienced by Inuit fishers, potential outcomes (in the context of existing literature), and community responses.

Table 6: Implications of change and community responses.

Implications of change	Potential outcomes	Community responses
Shorter fishing seasons	Limit the window of opportunity for fishing—can result in food insecurity and disturb Inuit livelihoods (Islam et al., 2014, McCubbin et al., 2015, Savo et al., 2017).	Two co-existing fisheries provide opportunities; the turbot fishery provides additional income, which is not the case in most other Arctic communities.
Safety concerns while traveling on ice for fishing/hunting	Exposure to accidents can limit the ability to engage in fishing activities and can diminish human capacity/agency (Clark et al., 2016a, Clark et al., 2016b).	Use of technology minimises vulnerabilities related to travelling on ice (GPS, powerful snowmobiles, VHF radios, satellite maps and weather updates via social media).
Weaker bonding among family members	Can weaken community cohesion (Armitage et al., 2011, Huntington et al., 2017, Cinner et al., 2018).	Community events such as food sharing events improve community cohesion. At such events, Inuit cook country food, eat, play games and share stories.
Lessening of workdays as their health does not allow them to engage in their fishing activities	Concern about food insecurity because people rely highly on fish as a critical source of protein (Collings et al., 2016, Huet et al., 2017).	Fishers share their catch with relatives and elders, especially those who are unable to fish and hunt. Income assistance is available for some Inuit (about 25% of the community population).
Inuit perceptions about reducing char fish population	Threat to the sustainability of char fishing (Roux et al., 2018).	The HTA and DFO along with the NWMB co-manage the char fishery (as outlined in the Nunavut Agreement Article 5).
Lessening aesthetic value of the community	Can affect the tourist/researchers' attraction of community (König, 2018).	Livelihoods are diversified and there is more reliance on fisheries.
Shrinking Arctic char market portfolio in fish plant	Can be a threat to the char commercial fishery (Cline et al., 2017).	There is a more diverse and stronger market portfolio for the turbot fishery, which creates more confidence in growing the turbot fishery.

Our work identified three key adaptive strategies of Pangnirtung Inuit that dominate community responses. First, 'diversification' is a common strategy in the areas of fisheries, country food, fish export markets, and livelihood activities. A wide range of food, income, and market options can improve the adaptive capacity of the fisheries system mainly through: a) year-round distributed income-generating activities that allow Inuit to afford alternative food sources (purchase from store), b) access to a wide range of country food will minimise vulnerability in terms of health issues and food insecurity, and c) multiple markets will improve the resilience of the local fishing industry in terms of adapting to changes in global trade. Diversification could be further improved, creating price choices/options among fishers in terms of selling their fish (for example, opening up a second fish buying unit). Nurturing diversity in a changing SES can increase creativity and adaptive capacity and set the system to reorganization and renewal (Folke et al., 2003, Folke,

2016). Also, diversity is identified as a source of systems resilience and a means of adaptation in the context of small-scale fisheries (Galappaththi et al., 2018).

Second, the use of technology for fisheries activities is a strategy employed mainly in response to safety-related vulnerabilities (Clark et al., 2016a, Clark et al., 2016b). For example, most fishers use GPS to mark good turbot fishing spots and as a direction guide for travelling on ice. Almost all fishers use VHF radios to communicate with the base station (community) for help while travelling on ice or on the sea for fishing. Furthermore, many Inuit use internet-based social media for weather updates, such as satellite images and changes in wind direction. Younger fishers and hunters who do not have a good knowledge of ice or the land are prone to take risks and go out ill-prepared. But because most young Inuit can use such technology, this potentially moderates knowledge gaps by improving human agency and enhancing adaptive capacity (Larsen and Fondahl, 2015, Brown, 2016, Folke, 2016), as also found in some Nordic countries and in Russian fisheries (Keskitalo et al., 2011).

Third, we recognise fisheries co-management as an adaptive strategy (Berkes and Armitage, 2010), mainly for dealing with changing fishing seasons by achieving a shared consensus of multiple stakeholders (Berkes and Armitage, 2010, Armitage et al., 2011). The co-management approach has multiple characteristics (Carlsson and Berkes, 2005, d'Armengol et al., 2018): partnerships between the government and local groups; vertical linkages for governance; the sharing of authority, responsibility and power; and learning-by-doing and adaptive management. Together these characteristics advance adaptation through a division of labour based on the respective comparative advantages for each partner. Achieving the shared interest of multiple parties minimises conflicts among partners (Armitage et al., 2008, Berkes and Armitage, 2010, Armitage et al., 2011, Galappaththi and Berkes, 2015, Fidelman et al., 2017). Used as a resource management approach in northern Canada for decades, particularly with indigenous groups (Armitage et al., 2008, Berkes and Armitage, 2010, Armitage et al., 2011), co-management as an adaptive strategy provides flexibility (Cinner et al., 2018) and other characteristics that a resource management system needs to deal with change (Appendix-Table S5).

Diversification, adoption of advanced technology and co-management are adaptive strategies that build resilience in Arctic fisheries systems to manage shocks and stressors associated with changes, and to adapt to climate change. In addition to these three key adaptive strategies, we identify four place-specific attributes that support adaptive strategies and shape community adaptation: Inuit worldviews, Inuit institutions, a culture of sharing and collaboration, and ILK systems (Appendix-Table S6). Each attribute has the ability to support adaptation under given circumstances. The combination of these four attributes will reduce system vulnerability and help build resilience of Inuit fisheries systems by increasing adaptive capacity. Four attributes, together or in combination with adaptive strategies, collectively influence the community's process of adaptation to change. For example, the implications of climate change impacts (such as changing sea-ice conditions that lead to limiting harvests) will be partly addressed by a broad range of adaptive responses such as the use of money saved from past turbot fishing, the selling of seal skins to the HTA, the hunting of caribou/fox and waiting patiently until conditions return to normal.

5. Conclusion

This paper examines the ways in which indigenous fishers experience and respond to change by assessing community adaptations of the Pangnirtung Inuit. Climate change creates multiple changes in Arctic fisheries systems; Inuit show multiple responses to adapt to these changes. The findings highlight three adaptive strategies (diversification, technology, and co-management) as well as the place-specific attributes (worldviews, institutions, culture of sharing, and ILK) that shape community adaptation. The study provides new insights for communities, scientists, and policymakers that may facilitate them to work together to support community adaptation. First, an understanding of the ways in which fishers experience and respond to change is essential to better understand adaptations; to carry out such an assessment, the resilience-based conceptual framework (place, human agency, collective action, institutions, ILK, learning) may be used. Second, the information required to link community adaptation realities to government plans to develop better fisheries adaptation policy may be explored under a co-management setting. Third, from the community perspective, an understanding of community adaptations can enable self-evaluation of community adaptation processes for future planning and adjustments.

Appendix A. Supplementary data

Supplementary material associated with this article can be found, in the online version.

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