STEM Fellowship Big Data Challenge 2019-2020

Changing Baffin Bay Fish Distribution and Their Effects on Inuit Communities

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I. ABSTRACT

The purpose of this study was to examine data on fish population shifts and ocean warming in the Davis Strait and Baffin Bay region, and consider how these shifts may affect Inuit communities. We examined data from 1950 to 2010 on fish sightings as well as trends in warming and decreasing salinity due to melting glaciers in that region. Specifically, we conducted generational analysis of various fish species alongside heat maps of fish spottings which were used to determine population migration trends for certain species. We found a recent shift in migration pattern's for several species of fish which may be correlated with the previously established ocean warming. This shift was observed in the species *Macrouidae*, *Myctophidae*, *Phycidae*, *Zoarcidae*, and *Salmonidae*. The migration of the *Salmonidae* is especially consequential due to the dependence of Inuit peoples on salmonidae for sustenance during certain parts of the year. Assuming that this link is causal, and that feedback mechanisms for glacial melting will only accelerate warming, we anticipate that this effect has the potential to upset traditional ways of life for Inuit communities in the region.

II. INTRODUCTION

Melting arctic glaciers have massive ecological consequences on both local and global scales. Previous research has established a direct correlation of melting ice caps and changing heat distributions. Current CMIP6 models do not account for large-scale ice-shelf melt [2]. In understanding the consequences of these changes, we can make further progress towards a more sustainable future that includes everyone.

This paper seeks to analyze one specific effect of these ecological changes by examining and quantifying the shifts in population location of fish species of the families *Salmonidae*, *Macrouidae*, *Myctophidae*, *Phycidae*, and *Zoarcidae*. This paper also compares these trends to data about the warming of the oceans to examine whether or not the fish may potentially be migrating due to water temperature changes. Finally, we examine how the migrations of these fish species will impact Inuit communities.

III. LITERATURE REVIEW

Previous literature has established that meltwater will provide a worldwide temperature drop of up to 0.4 degrees Celsius by 2055. However, these changes will not be uniform, as the Southern hemisphere will become drier and the Norther hemisphere wetter. This will increase the formation of of Antarctic sea ice and warm its subsurface ocean. Since this analysis was limited to a low-emission projection, it is unclear what increasingly severe ramifications this poses for salinity, heat distributions, local and global ecosystems, and Inuit cultures should worldwide emissions be higher than expected.

One of the most important accelerators of climate change are positive feedback loops, which are defined as environmental mechanisms whose output amplifies the effect of the system. The most relevant feedback loop for our research project is ice-albedo feedback, a phenomenon where melting ice and snow reduces the reflection of sunlight off the earth and increases heat retention, thereby causing even more ice and snow to melt[4]. This means that the effects of Arctic sea ice on fish populations will only grow stronger and faster with time.

From the month's of April through June, Arctic Char and other members of the *Salmonidae* family have been estimated to make up 35% of the diet by mass of some coastal Inuit communities from April to June and 15 % from July to September. Furthermore, an Inuit Tapiriit Kanatami (ITK) paper on Inuit food policy reported that due to their remoteness and inaccessibility, the cost of a basic nutritious diet for a family of four was $395 to $460 a week, while in Ottawa that number was $226 [5]. Based on this data, it is a reasonable assessment that without access to the fish populations they have relied on for centuries, Inuit communities would struggle to source a nutritious diet.

IV. MATERIALS AND METHODS

We first sourced our data from a database of fish sightings up to the year 2011 maintained by the Conservation of Arctic Flora and Fauna. This database focused their observations in the eastern shore of Baffin island. After importing the data into a Microsoft Excel spreadsheet, all fish families with more than 200 sightings, or 0.1 percent, of the approximately 65,000 were sorted into their families and the latitude and longitude of the sightings were plotted by family to generate 26 unique data sets, one for each family of fish. These profiles were further split into decade-wide sightings, sightings over five year intervals, and sighting every year over the last twenty years to investigate the changing habitats of these fish in the Arctic. We then selected species and plotted their sightings based on the location and time of each sighting. In order to track populations over time, we used a gradient map for families with fewer data points and computed the mean latitude and longitude of each year's sightings for families with more data points.

We used NASA heat maps and other previously published research to find areas of the Arctic ocean that are experiencing significant warming. These papers generally focused on the melting of the Greenland ice-shelf. All relevant results were mapped onto the heat maps.

The tools used consisted of Microsoft Excel 2019, as well as Python. Excel 3D Maps was used to create each map and scatter plot, while a Python script was used to compose a gradient in order to show generational shift across time.

There are 18 degrees of freedom for Figures 10 and 11. The critical-r value, at a confidence interval of 0.005, is 0.561 for a one tailed test. We utilize a one-tailed test because the heat maps dictate a trend in one direction, which is to be tested. Respectively, there are r-values of 0.762, and -0.730 for Fig. 10 and Fig. 11 respectively, so this both are statistically significant to 99.5 percent.

Fig. 10 has an R^2 value of 0.5803 which also indicates some trend exists. The variance, while indicated by the value, can be explained through the semi-consistent breeding periods of salmon. The same reasoning applies to Fig. 11 which has an R^2 value of 0.5331.

V. RESULTS

Using Baffin Bay glacial melt maps, we first analyzed the ice levels, inflows, and outflows, as shown in Fig. 1.

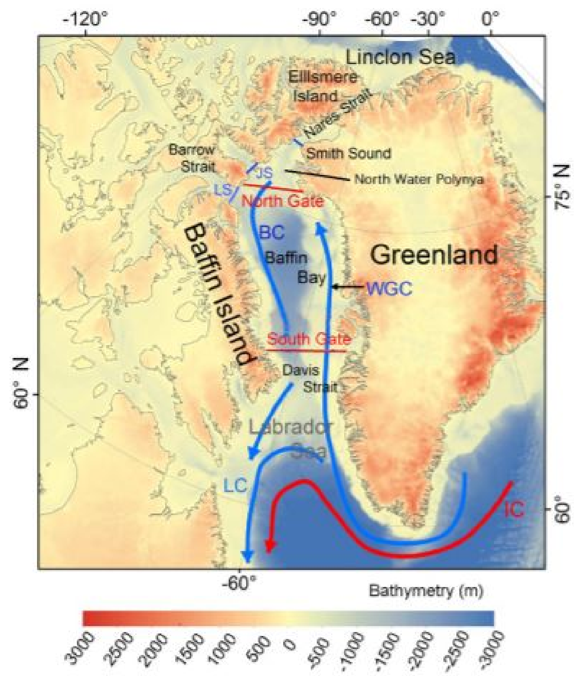

Figure 1. Average Current Inflows and Outflows of the Baffin Bay area. The West Greenland Current (WGC) that runs along the Greenland Shelf carries water around the Baffin Bay, into the Baffin Current (BC) back to the Davis Strait before emptying in the Labrador Sea. Credit to Bi et al.

Water is circulated across the Davis Strait, causing the temperature off the Greenland ice-shelf to influence the entire bay. This causes the Baffin Bay area to act as a heat sink.

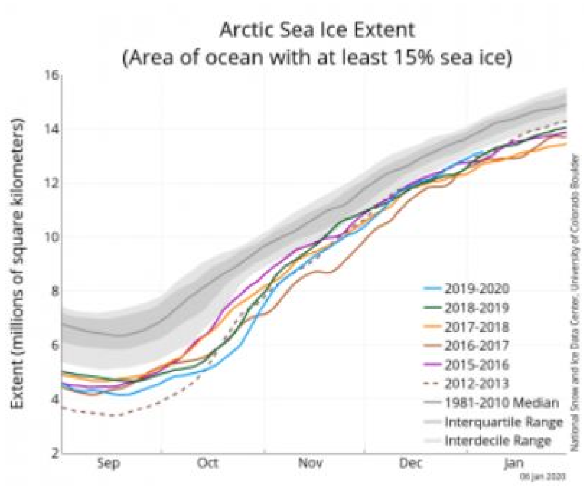

Figure 2. The graph shows the extent of Arctic sea ice until January 6, 2020, along with daily data for four previous years and the record low year [2].

The extent of Arctic Sea ice has been gradually lowering at both the maximum and minimum in January and September respectively as seen in Fig. 2. This trend attests to the positive feedback mechanism explained in the Introduction, but is also indicative of glacial melt.

The substantial air temperature increase in the Baffin Bay area is the first signal that some deviation is occurring within the climate. The southern piece, near Quebec as indicated by Fig. 3, is especially interesting. However, in order to analyze fish populations we cannot use the surface temperatures.

The warming and freshening of the Baffin Bay has yielded in some research which indicates somewhat to very significant warming trends [7]. Specifically greater than +2 °C waters of the West Greenland Current below 200 m depth centered near 60 °W longitude were recorded. Davis Strait, between 65 °N and 67 °N latitude as well as east of 58 °W longitude indicated a barely significant warming trend at 400–600 m depth. The temperature change was 0.10 ± 0.09 °C/decade. The narrow shelf and slope region off Greenland, south of 63 °N latitude and inshore of the 1000 m isobath have about 0.16 ± 0.10 °C/decade.

Each gradient map, from Fig. 5 to Fig. 9, have a red area indicating this warming area.

This monthly arctic average, seasons non withstanding, indicates a clear negative trend

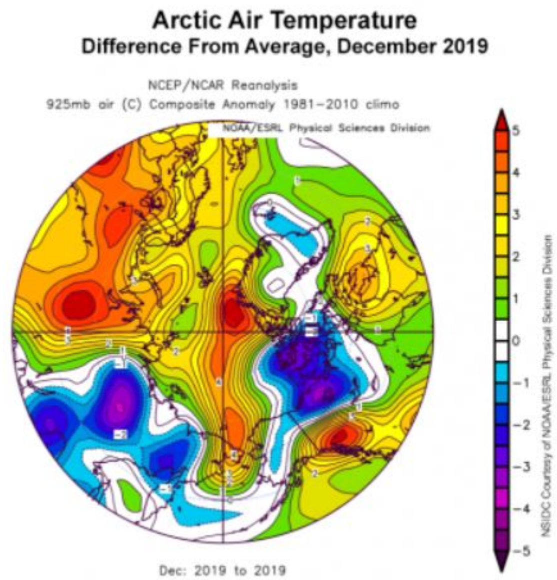

Figure 3. The map shows the deviation in Arctic temperatures from the average of the entire region in 2019. The top right quadrant contains the Baffin Bay area and shows substantial warming around the southern area [2].

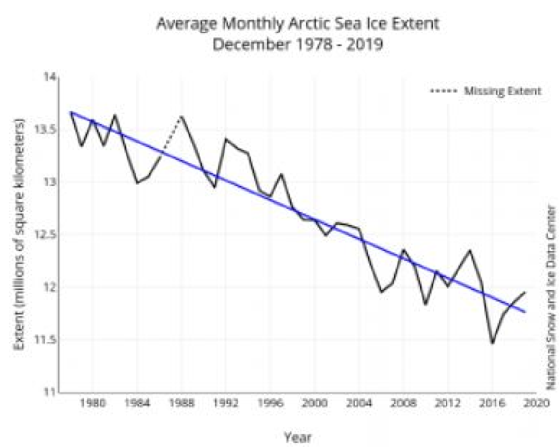

Figure 4. The graph above shows the extent of Arctic Sea Ice from 1980 to the present and highlights its significant downward trend. [2]

that attests to the melting ice of the Arctic. Fig. 4 feeds directly into a positive feedback loop, due to the premise that lower albedos by lower ice sheet coverage, increase solar absorption.

The *Synaphobranchidae* family was selected as an example of a species which did not

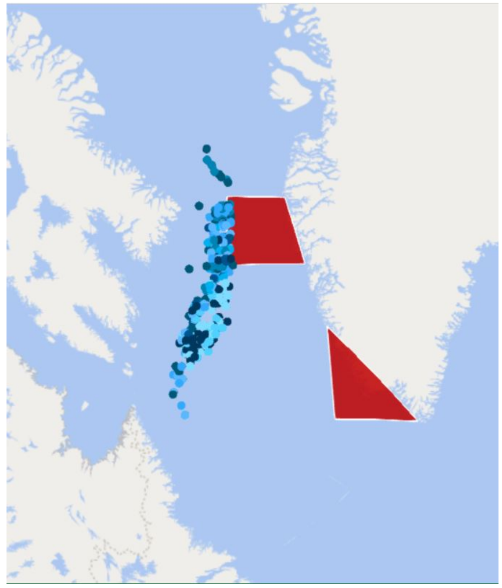

Figure 5. This map shows the plots all of the sightings of fish from the family *Synaphobranchidae*, with more recent sightings being coloured as a darker shade of blue. The red areas indicated on the map correspond to areas with high sea temperature warming.

undergo much migration due to warming waters. This is most likely because the *Synaphobranchidae* are a family of eels who live on the seabeds of the Arctic ocean. They are native to tropical waters, and as such are more resistant to temperature change. Thus, *Synaphobranchidae* was used as the control as Fig. 5 attests to their localized population in the center of the Davis Strait/Baffin Bay area. However, other deep sea fish are much more sensitive than the *Synaphobranchidae* and will move due to these temperature changes.

The *Macrouridae* family are also a deep sea fish, but their range has recently grown to encompass the northern shore of Baffin Island as seen in Fig. 6. This may be because they prefer the waters of the continental shelf, and conditions in the North have also become more favourable while their usual range has not changed in condition. That is why the *Macrouridae* have not yet disappeared from their traditional habitat southeast of Baffin island. However, there is a population shift towards the northern end.

The *Myctophidae* family displays much more significant migration than species previously mentioned, abandoning their traditional habitats altogether as seen from Fig. 7. *Myctophidae* are more commonly known as lanternfish, and they are known to surface to depths of 10m-100m at night. This means that surface temperatures have a much greater impact on the habitability of particular pieces of ocean and could be a potential trigger for their

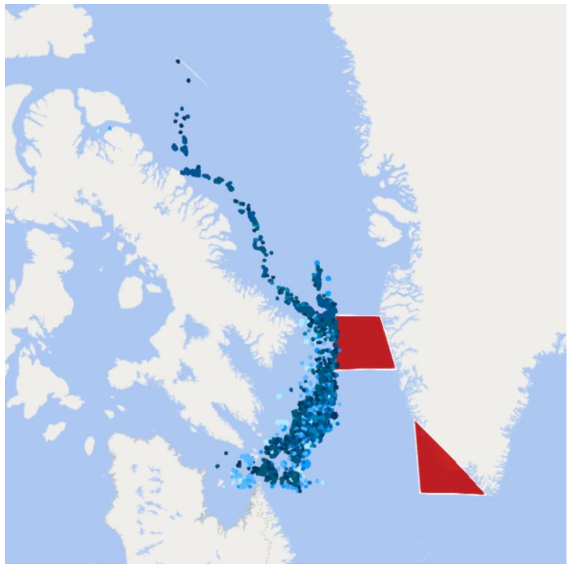

Figure 6. This map shows the plots all of the sightings of fish from the family *Macrouidae*, with more recent sightings being coloured as a darker shade of blue. The red areas indicated on the map correspond to areas with high, significant sea temperature warming.

northward migration. Similar to the *Macrouidae*, the *Phycidae* family displays an extension of its range without abandoning its previous habitats as seen in Fig. 8. The *Phycidae* are ecologically very similar to the *Gadidae* family of cods, which are a mix of both bottom and surface dwelling fish. The northward migration, then, is just an extension of the zones of habitability of the coast of Baffin Island that the *Phycidae* can take advantage of and begin filling local niches.

Perhaps most intriguing, *Zoarcidae* shows a cleft population with many either migrating northwards or southwards into the Hudson Bay area. This is likely due to both the temperature shift as well as their incredibly deep habitat range.

For data sets with over 6000 points, a gradient map does not provide significant results due to the limited palette available as well as cluttering of data points. As such, an average was employed for *Salmonidae*. This was separated by latitude and longitude.

Outliers were calculated using the equations,

$$Q_1 - 1.5(Q_3 – Q_1)$$

$$Q_3 + 1.5(Q_3 – Q_1)$$

for the low and high outliers respectively.

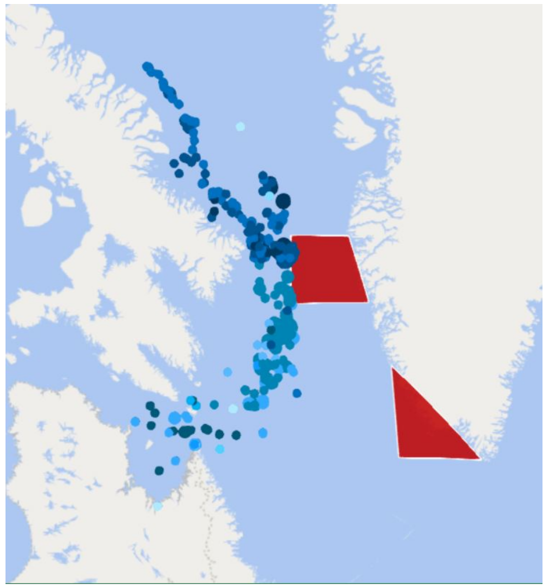

Figure 7. This map shows the plots all of the sightings of fish from the family *Myctophidae*, with more recent sightings being coloured as a darker shade of blue. The red areas indicated on the map correspond to areas with high, significant sea temperature warming.

From Fig. 10 and Fig. 11, we see some trend of a north-eastern migration. This is consistent with prior observations and the outlined literature review. It is important to note that with a population as large as *Salmonidae* any change is significant, especially considering other factors that may influence migration including breeding periods and maturation.

The significance testing found under Materials and Methods suggested that these findings are significant to a statistical degree of 0.995.

VI. DISCUSSION

While we cannot conclusively establish a concrete causation between the presence of fish species and the changing temperatures of the ocean, the correlation is strong enough to warrant further research. Previous research has indicated that *Salmonidae* require specific temperatures of water in order to properly reproduce, which means that is very feasible the changing temperatures is one factor behind the move. However, there may be many other factors behind the migration that we have not considered, such as changing salinity and pH levels as well as other ocean conditions which are constantly in flux as well.

Whatever the reasons behind the migration are, its impacts can be clearly seen in the

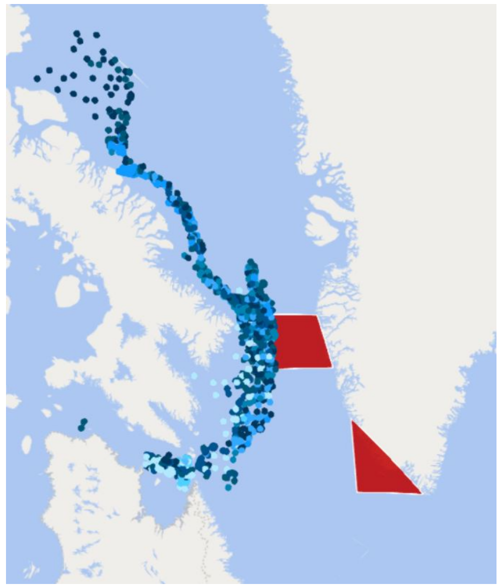

Figure 8. This map shows the plots all of the sightings of fish from the family *Phycidae*, with more recent sightings being coloured as a darker shade of blue. The red areas indicated on the map correspond to areas with high, significant sea temperature warming.

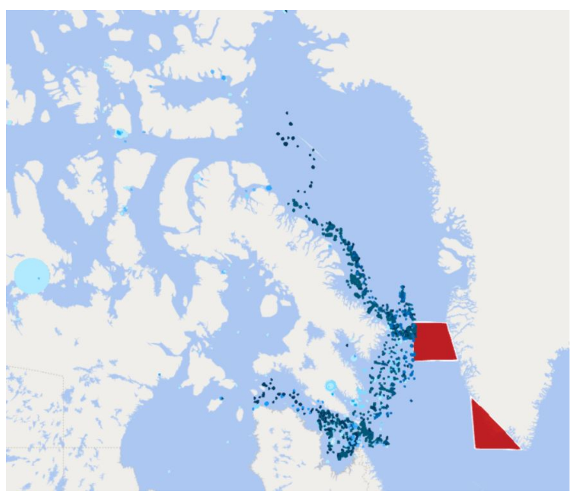

Figure 9. This map shows the plots all of the sightings of fish from the family *Zoarcidae*, with more recent sightings being coloured as a darker shade of blue. The red areas indicated on the map correspond to areas with high, significant sea temperature warming.

Canadian Arctic, especially among the predominantly Inuit communities there. The diet of many Inuit communities rely on fish, especially during the late winter and early spring months, especially Arctic char and whitefish. Between April and June, fish of the *Salmonidae* family make up up to 87 percent of Inuit diet by mass. Our analysis above has shown the

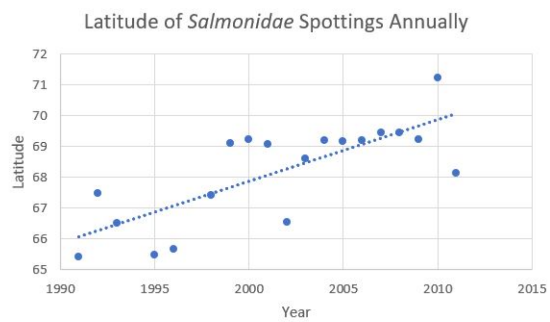

Figure 10. This graph shows the change in the average latitude of the salmon population from the year 1991 to 2011, with two outliers removed in years with very few data points, and that satisfied the computational analysis. This graph demonstrates a consistent northward migration of *Salmonidae* into more suitable waters.

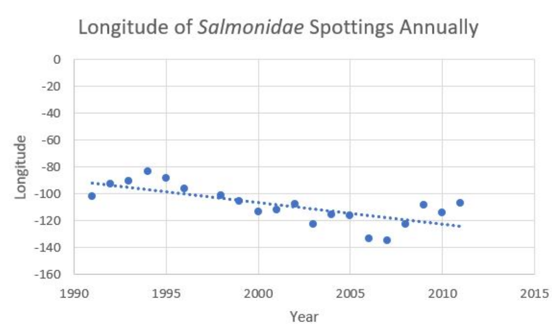

Figure 11. This graph shows the change in the average longitude of the salmon population from the year 1991 to 2011, with three outliers removed in years with very few data points, and that satisfied the computational analysis. This graph demonstrates a consistent eastward migration of *Salmonidae* into more suitable waters.

correlation between changing ocean temperatures and the migration of these species of the family *Salmonidae* away from traditional Inuit fishing grounds and ancestral communities established due to the presence of these vital food sources. This means that these communities may be forced to relocate after hundreds of years of habitation and tradition or food must be imported at a great cost to keep these communities alive.

VII. CONCLUSIONS

Our final results indicate that numerous fish populations are demonstrating some shift away from their native maturation grounds, which is consistent with Baffin Bay warming analysis. A strong correlation exists, where fish like *Salmonidae* and *Myctophidae* demonstrate a strong aversion to the warming waters off Greenland. This both complements current climate change models like CIMP5 which do not include meltwater and poses pressing concerns for Inuit populations. Because of the outlined ice-albedo positive feedback loop, these concerns will likely only compound over time. Current studies on biodiversity in the Baffin Bay are seeking funding, and future endeavours should place focus on research assisting Inuit communities. We found that changing ocean temperature owing to increased Arctic ice melting has some impact on the marine life of the Arctic and thus impacts the Inuit communities that depend on them. Many Inuit communities rely on traditional knowledge passed down over generations to catch fish such as whitefish and Arctic char. Inuit communities will likely not be able to apply their traditional methods of fishing, thus disrupting their way of life.

VIII. ACKNOWLEDGEMENTS

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