Assessing reasons for changes in the condition of Deception Bay Arctic charr (*Salvelinus alpinus* L.)

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Figure 1. A Deception Bay Arctic charr

Background

- The Raglan Mine has collected biological data on Deception Bay Arctic charr (*Salvelinus alpinus*) through an employee sport fishing program, which since 2004, has documented a decline in fish condition.
- Concerns expressed by the local Hunting, Fishing, and Trapping Coordinating Committee (HFTCC) regarding the importance of Arctic charr to the surrounding communities, as well as the effect of growth and condition on population dynamics and survival[1, 2, 3], have triggered additional scientific studies to determine the possible causes of the observed decline.

Figure 2. Map of the Nunavik region of Québec. Sampling sites (outlined in red).

Figure 3. Gillnetting sites in the Deception Bay and River during August 2016.

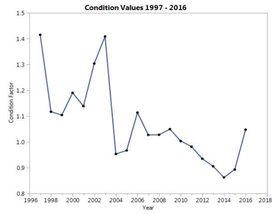

Figure 4. The decline in somatic condition of Deception Bay Arctic charr.

Objectives

- To examine whether physiological processes associated with the period of marine residency may be negatively affected by anthropogenic stressors related to mining activity in Deception Bay. Specifically, whether the observed declines in the somatic condition of Deception Bay Arctic charr are the result of significant differences in total mercury THg concentrations between sites, while also investigating the relationship between (THg) concentrations and feeding patterns ($\delta^{13}C$) during the marine residency.

Methods

Figure 5. Gillnetting in Deception Bay

Figure 6. Dissecting an Arctic charr

Figure 7. Performing a plankton trawl

Sample Collection

- Anadromous Arctic charr were captured at Deception Bay (n=200) and a reference site near Aupaluk, Québec (n=155) in August 2016. The reference site had no nearby commercial fishing or mining activities. Additional archival THg data collected from Nepihjee River Arctic charr near Kuujjuaq, Québec was included as a second reference site.
- Tissue samples (liver and muscle tissue, gonads, stomach contents, and otoliths) and biological data (fork length (cm), weight (g), gonad weight (g), and reproductive maturity) were collected.
- To establish the somatic condition of post-winter fish prior to their marine migration and feeding, samples were collected in Deception River headwater lakes Duquet and Françoys-Malherbe in May 2017.
- These samples were acquired via a collaborative fishing program using local Inuit fishers and the Nunavik Research Centre, and provided tissue and data for several different analyses.

Methods Continued And Preliminary Results

Hg Analysis

- THg analysis was performed with a direct mercury analyzer (DMA) (DMA-80, Milestone Inc., Shelton, USA).
- Tissue was evaluated in triplicate with certified reference materials from the National Research Council of Canada (TORT-3 and DOLT-4), as well as blanks, to establish accuracy and recovery rates.

$\delta^{13}C$ Analysis

- Stable isotope analysis was performed with a Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba Elemental Analyzer (CHNS-O EA1108, Carlo Erba, Milan, Italy).
- Duplicates were run every 12 samples and measurement precision was determined using laboratory working standards (IAEA-CH_3 + CH_6) cross calibrated to International Atomic Energy Agency (IAEA) standards: CH_6 for $\delta^{13}C$.

Preliminary Results

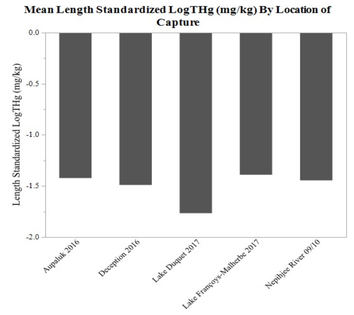

Figure 8. Mean length standardized LogTHg (mg/kg) did not vary significantly among the 4 sampling sites and the additional Nepihjee River data set ($F_{(4,117)}$ = 1.8950, p=0.1159).

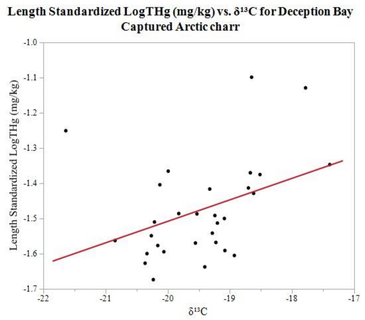

Figure 9. Length standardized logTHg (mg/kg) significantly increased (p=0.0344) with rising $\delta^{13}C$ values in Arctic charr muscle tissue collected from Deception Bay during August 2016.

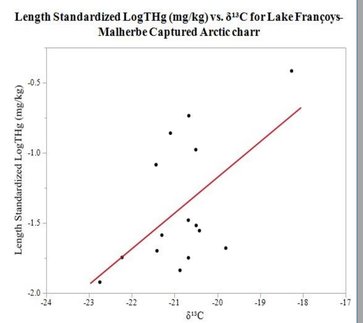

Figure 10. Length standardized logTHg (mg/kg) significantly increased (p=0.0264) with rising $\delta^{13}C$ values in Arctic charr muscle tissue collected from Lake Françoys-Malherbe during the Spring 2017 Fishery.

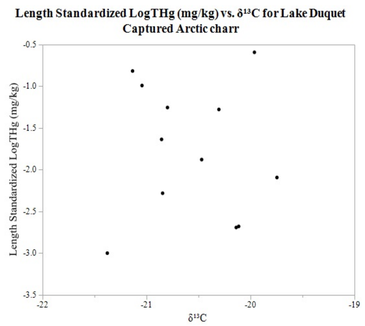

Figure 11. The negative relationship between standardized logTHg (mg/kg) and $\delta^{13}C$ was not significant (p=0.9053) in muscle tissue from Lake Duquet captured Arctic charr during the Spring 2017 Fishery.

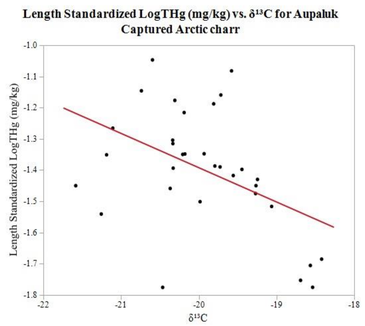

Figure 12. There was a significant (p=0.0023) negative relationship between length standardized logTHg (mg/kg) and $\delta^{13}C$ in Arctic charr muscle tissue collected from the reference site near Aupaluk.

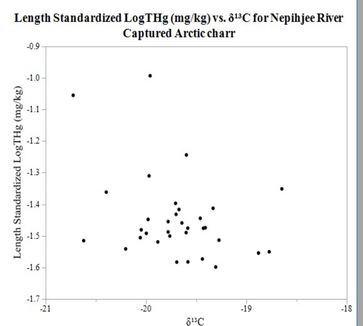

Figure 13. The negative relationship between length standardized logTHg (mg/kg) and $\delta^{13}C$ in the muscle tissue collected from Nepihjee River captured Arctic charr was not significant (p=0.0604).

Discussion

- Differences in mean THg values between sites were not significant ($F_{(4,117)}$ = 1.8950, p=0.1159) suggesting that anthropogenic activity may not be singular cause of condition declines. However, positive THg-$\delta^{13}C$ relationships are not consistently observed in the literature[4, 5], or elsewhere in Ungava Bay, which may point to an ecological cause of poor condition.
- The positive THg-$\delta^{13}C$ relationship may be influenced by: (1) the role of $\delta^{13}C$ in estuarine environments[6, 7] and (2) size related prey use, supported by initial diet observations.
- In Deception Bay, a dietary shift to amphipods farther from the freshwater influences of the River by larger fish may be causing the positive THg-$\delta^{13}C$ relationship, given known $\delta^{13}C$ interactions and the relationship between growth and offshore feeding in Arctic charr[8, 9]. In Aupaluk, the negative relationship appears to be associated with a prey shift from amphipods to fish as Arctic charr size increases.
- These statements are supported by the positive THg-$\delta^{13}C$ relationship in Lake Françoys-Malherbe, but not in Lake Duquet. Lake Françoys-Malherbe is dominated by larger (p<0.0001), predominately anadromous fish, while Lake Duquet is populated by a greater number of smaller and landlocked Arctic charr.

Next Steps

- Continued stomach content analysis.
- Examine sea ice clearance and temperature data to determine whether declines in somatic condition may be related to large scale ecological changes. Warming temperatures may have altered historic prey distribution prompting Deception Bay Arctic charr to rely on lower density prey items, resulting in the observed declines in condition.

References

1. Wootton, R. J. 1990. Ecology of Teleost Fishes. Chapman & Hall, United Kingdom.
2. Reist, J. D., F. Wrona, T. D. Prowse, M. Power, J. B. Dempson, J. R. King, and R. J. Beamish. 2006. An overview of effects of climate change on selected Arctic freshwater and anadromous fishes. *Ambio* **35**:381-387.
3. Murdoch, A., J., and M. Power. 2013. The effect of lake morphometry on thermal habitat use and growth in Arctic charr populations: implications for understanding climate change impacts. *Ecology of Freshwater Fish* **22**:453-466.
4. Power, M., G. M. Klein, K. R. A. Guiguer, and M. K. H. Kwan. 2002. Mercury accumulation in the fish community of a sub-Arctic lake in relation to trophic position and carbon sources. *Journal of Applied Ecology* **39**:819-830.
5. Rognerud, S., J. O. Grimalt, B. O. Rosseland, P. Fernandez, R. Hofer, R. Lackner, B. Lauritzen, L. Lien, J. C. Massabuau, and A. Ribes. 2002. Mercury and organochlorine contamination in brown trout (*Salmo trutta*) and arctic charr (*Salvelinus alpinus*) from high mountain lakes in Europe and the Svalbard archipelago. *Water, Air and Soil Pollution: Focus* **2**:209-232.
6. Attrill, M. J., S. D. Rundle, A. Fraser, and M. Power. 2009. Oligochaetes as a possible entry route for terrigenous organic carbon into estuarine benthic food webs. *Marine Ecology Progress Series* **384**:147-157.
7. Connolly, R. M., T. A. Schlacher, and T. F. Gaston. 2009. Stable isotope evidence for trophic subsidy of coastal benthic fisheries by river discharge plums off small estuaries. *Marine Biology Research* **5**:164-171.
8. Forseth, T., O. Ugedal, and B. Jonsson. 1994. The energy budget, niche shift, reproduction and growth in a population of Arctic charr, *Salvelinus alpinus*. *Journal of Animal Ecology* **63**:116–126.
9. Langeland, A., and J. H. L'Abée-Lund. 1998. An experimental test of the genetic component of the ontogenetic habitat shift in Arctic charr (*Salvelinus alpinus*). *Ecology of Freshwater Fish* **7**:200–207.