4.2 Growth variability and mercury tissue concentration in anadromous Arctic charr (Arctic charr)

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Don Ross (Aurora Research Institute); Trevor Lucas (Community of Sachs Harbour); Susie Malgokak (Community of Ulukhaktok, NT); Larry Dow (Fisheries and Oceans Canada - Central & Arctic Region); Sheila Nasogaluak (Fisheries Joint Management Committee (FJMC)); David Haogak, John Jr. Lucas, Ifan Thomas (Parks Canada - Western Arctic Field Unit); Earl Esau (Sachs Harbour Community Member); Kevin Gully (Sachs Harbour Hunters and Trappers Committee); Lillian Kanayok (Ulukhaktok Hunters and Trappers Committee)
ABSTRACT

The project was designed to build on prior work that examined probable climate change related growth and contaminant impacts on land-locked populations of Arctic charr by extending the analysis to include important migratory and land-locked populations of Dolly Varden Charr in the Yukon Territory. There is a notable lack of data for Dolly Varden charr, despite the importance of the species as a country food resource. Here we plan to use existing archival tissue samples to construct an historical spatial baseline for THg levels in Dolly Varden charr against which contemporary data can be compared to examine the impacts of climate change and development activities on current THg levels. Work will also be extended to include comparative examination of Dolly Varden charr in the Beaufort and a determination of where and how they function in Beaufort Sea foodwebs likely to be affected by oil and gas exploration activities. The project will also continue important partnering work begun with Nunavik Research to examine the marine life-history phase of Ungava Arctic charr introduced into a previously unoccupied river system. Previously PIT-tagged fish have begun to return in numbers and we are now able to estimate annualized marine growth and compare that growth to monitored water temperatures as a means of estimating site-specific growth temperature relationships using oxygen stable isotope methods. Results are critical data for assessing the possible impacts of climate change Nunavik Arctic charr and understanding how overall availability of Arctic charr will respond to predicted climate changes. To further improve conceptual understanding of temperature-growth affects location-temperature tags will be inserted into Arctic charr and monitored via acoustic receivers to track temperature use in both the marine and freshwater environments. In concert with growth studies, the project has been monitoring the ecological impacts of Arctic charr introductions and found them to be negligible. This effort represents the first attempt to scientifically evaluate the consequences of northern ecosystem manipulation and has provided important data and insights for management purposes by showing it is possible to proactively manage Arctic charr stocks with minimal ecological consequences. Finally work continues on genetic typing of Arctic charr populations to improve our understanding of how climate change may impact the immunological capabilities of Arctic charr and their abilities to deal with new diseases and pathogens likely to be introduced into northern environments as a result of changing environmental conditions. All study generated information will contribute to the improvement of management abilities to make informed decisions about the risks associated with continued country food consumption in the face of changing conditions in the Arctic. This project also identifies key environmental indicators of changes in Arctic Char (Salvelinus alpinus) growth using both quantitative (ecological) and qualitative (Indigenous Knowledge) data by linking community-based monitoring, local expert Indigenous and ecological knowledge. Arctic Char is a staple subsistence resource for Inuvialuit on Banks and Victoria islands in the Northwest Territories, Canada. In recent years, significant climate variability and change has been observed in the area, raising local concerns about how this variability will affect subsistence resources. Residents in local communities are the first to directly observe these changes and variability in local the climate and the effects on their land, water and animals. Centuries of knowledge and observations about the environment and natural resources exist among Inuvialuit hunters and fishers. Local expert Traditional Knowledge (IK) can complement our scientific understanding of environmental variability and change and its effects on Arctic species. Community-based monitoring (CBM) provides an opportunity to better understand the current status of Arctic species and can form the basis for understanding and preparing for future changes in Arctic species in light of climate variability and change effects. Using a mixed-methods approach to research is one way in which ecological scientific and Traditional Knowledge can be brought together to complement one another and provide a more thorough understanding of northern fish species in a changing environment.
KEY MESSAGES

Growth variability and mercury tissue concentration in anadromous Arctic charr component

- Large sample analysis of high Arctic Arctic charr indicate that accumulation of mercury in fish is exposure dependent and independent of growth rate, with large and small individuals from within the same age-groups having no significant difference in mean THg levels. Results, therefore, provide no support for the growth dilution hypothesis.

- Latitudinal comparisons of multiple Arctic charr populations found to support the hypothesis that anadromous Arctic charr have lower THg than non-anadromous conspecifics across a range of latitudes in eastern Canada, but the difference in THg between the life-history types was variable. Results indicate knowledge of differences among specific populations cannot be reliably used to infer likely differences among other populations.

- THg concentration levels in baseline samples of Dolly Varden charr were generally low, i.e. within consumption guidelines, but differences exist among populations by location and life-history type. The significance of other biological factors (e.g., length, age) is not understood at present.

- There is regional variability in the response of Arctic charr populations to variations in marine temperatures, with the response controlled by regional differences in nearshore marine productivity and population maturation schedules.

- Ungava Bay Arctic charr are more responsive to increases in marine temperatures in terms of growth than are Labrador Arctic charr. Thus regionally-specific study of Arctic charr populations will be needed to accurately predict climate-related impacts and differences in population responses to temperature increases will eventually hold significant implications for local availability of Arctic charr.

- Arctic charr can be successfully introduced to previously uninhabited river and lake systems and have minimal to no impact on existing ecosystem structure or function. Studies of the Nepighjee River system introduction have shown only minor impacts, with all changes occurring within the bounds of year to year variation in ecosystem state.

- Successful introductions of Arctic charr rely on the relative immaturity of northern ecosystems, the availability of open niches not exploited by other fish, the dietary flexibility of Arctic charr and the fact that as adults the majority of their energy requirements are met during summer periods of marine residency and feeding.

Impacts of environmental change on charr in the Inuvialuit Settlement Region component

- For centuries, and still today, fishing and hunting of local natural resources have been a source of food and a part of the culture of the Inuvialuit of the Western Arctic region. Climate change is affecting northern species on which the Inuvialuit rely for food including their fish resources.

- Local expert Indigenous Knowledge of fish shows the ocean charr seem to be getting bigger over the past decade and that salmon are showing in the area in large numbers in the past five years. In the past, only one or two salmon would be seen every few decades. Now they are seeing 20-30 per year in their near shore nets. Local expert Indigenous Knowledge of the environment shows that air temperatures are warming, the ocean water is warming, the sea ice is thinner, the winds are stronger and there are more rain and storm events.

- The warmer temperatures are affecting lake ice resulting in earlier break-up and later freeze-up and thus potentially longer growing seasons for the charr. Sea ice thickness is also changing in the regions surrounding both Sachs Harbour and Ulukhaktok. These changes started occurring 12-17 years ago.
• Preliminary scientific analysis of the Arctic charr otoliths from the Sachs Harbour region show a larger increase in growth in the fish in approximately a decade ago in fish from different lakes across a range of age classes which coincides with extreme environmental conditions in the region.

• Studying Arctic charr, Arctic freshwater ecosystems and the local environment using both scientific and local expert Indigenous Knowledge has produced a more robust suite of monitoring indicators that incorporate local expertise and understanding of the resource.

• The importance of charr as a subsistence food to Inuvialuit Settlement Region communities requires on-going and effective community-based monitoring plans (CBMPs) that ensure continual local observation and monitoring to contribute towards effective proactive management of this valuable resource in light of the effects of climate variability and change.

OBJECTIVES

A key objective is to address critical knowledge deficiencies concerning THg levels in populations of Dolly Varden charr and to relate differences among populations to variations in population-specific biological characteristics. A second key objective is to improve associated knowledge of the marine life-history phase of Dolly Varden charr in the Beaufort Sea in relation to other competing anadromous species and the foodwebs within which they feed. A third key objective was continuation of the long-term study of the effects of Arctic charr introductions in the Ungava region and of marine habitat use and growth in relation to temperature for Arctic charr in the same region as a means of capacity building (i.e. training of Inuit technicians) and improving scientific-based abilities to predict the consequences of climate warming.

Specific objectives for the Dolly Varden charr (DVC) Beaufort marine foodweb component:

• To determine the position and role of DVC in Beaufort Sea nearshore foodwebs.

• To compare and contrast the position and role of DVC to other key anadromous fish species (e.g., cisco) as a means of assessing baseline conditions for key fisheries resources.

• To compare and contrasted with IPY-related studies of anadromous Arctic charr in the eastern Arctic as a means of enhancing overall understanding of the trophic position and role of charrs in the Arctic marine environment.

Specific hypotheses tested in the Dolly Varden charr Thg component:

• Spatial differences in THg concentrations exist among populations of Dolly Varden charr in the Yukon, but as noted for other fish species, there will be no significant trend in differences either by latitude or longitude.

• Measured differences in THg levels among individuals will be correlated with trophic level and feeding, with THg increasing as δ¹⁵N increases and δ¹³C decreases.

• Measured THg levels will be positively correlated with the size and age of tested fish.

• No significant temporal trend in THg concentration levels measured in Dolly Varden charr will be observed, as has been noted for other studied fish species in the Arctic. If trends are observed, the sub-hypothesis that the direction and magnitude of any observed trends will be the same at all sites will be tested.

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Specific hypotheses tested in the Arctic charr introduction impacts component:

• The introduction of Arctic charr will shift the isotopic ratios of resident fish species with pelagic and littoral dietary preferences.

• The introduction of Arctic charr will increase omnivory in lake trout diets as a result of Arctic charr becoming a prey resource.
• The introduction of Arctic charr will alter food web metrics by increasing the overall vertical food web length and forage fish redundancy within the fish community, while having no effect on niche diversification at the base of the food web or other qualitative characteristics of the resident fish community trophic structure.

• The specific hypothesis to be tested in the Arctic charr marine thermal habitat use component:

• Arctic charr experiencing warmer marine habitats will evidence increased individual growth rates in comparison to conspecifics using cooler marine habitats under the assumption that food was not a limiting factor.

Specific research objectives include:

• To use a collaborative and multidisciplinary approach to determine effective environmental and biological indicators which can be used by Inuvialuit Settlement Region (ISR) communities to monitor charr.

• Conduct new and innovative research on Indigenous Knowledge in the social sciences linked to scientific studies on Arctic resources.

• Examine meteorological and hydrological data for the areas surrounding the study sites.

• Characterize lake habitat conditions and compare between study lakes.

• Examine IK-derived environmental indicators of change in growth for local charr identified through IK interviews with local experts.

• Examine potential relationships between annual environmental conditions (using IK indicators) and annual growth rates of Arctic charr.

• Identify effective indicators for community monitoring and fisheries management purposes with community input.

• Use Indigenous Knowledge and local input and expertise to contribute towards creating effective long-term CMBPs for charr in the ISR and all northern communities.

**INTRODUCTION**

The charr Project as currently configured has several key research aims each of which form the focus a project component. Building on the successes of successful collaborations with Nunavik Research, component 1 of the project will focus on continue the monitoring and tagging of Arctic charr using the Nepihjee fishway to build a data time-series on marine thermal habitat use and the effects of environmental variability on Arctic charr marine survival and growth using PIT-tagging and oxygen isotope methodologies. The work will be expanded to include a site on Fraser River (Nunatsiavut) where baseline tagging data from the 1980s exist and will eventually involve the deployment of acoustic or data storage tags (DSTs) to gain a detailed picture of the marine habitat use by individual fish. Such tagging will permit the collection of high frequency observations on the temperatures and depths used by fish, will allow the behaviour of Arctic charr to be connected directly to changes in the marine environment, and will provide important biotic response observations to complement detailed oceanographic research on marine environmental change being conducted in other ArcticNet projects. Component 2 of the project seeks to address known data deficiencies concerning mercury contamination levels in Dolly Varden charr (DVC). Dolly Varden charr are of significant cultural and dietary importance for the Inuvialuit and Gwich’in, but only limited attempts have been made to study the total mercury (THg) levels and trends in DVC. For example, searches of the ISI Web of Science yielded only a single primary scientific literature reference to THg levels in DVC and routine assessment of THg levels in DVC has not been included in NCP or AMAP related programs or reports. To construct a baseline for the species, research will use archived tissue samples available through DFO (1986 on) to construct spatial and temporal profiles of THg in DVC for relevant populations of concern. THg data will also be combined with age, length, life-history type and trophic position information obtained from parallel stable isotope analyses to determine the importance of these factors for determining overall THg levels in DVC, thereby creating a data set to complement the
extensive data sets that already exist for Arctic charr. Component 3 of the project will use available archival sample data to address critical questions with respect to the function and structure of Beaufort Sea foodwebs, particularly as they pertain to anadromous fish species. There is, currently a notable lack of understanding about Beaufort Sea food webs in general and of the integrative role of DVC within Beaufort foodwebs. For example searches of the ISI Web of Science and Cambridge Scientific Abstracts yielded only 24 primary scientific literature references to Beaufort foodwebs. Most reference the roles of microbial and geophysical processes or marine mammals. None referenced the position or role of key fish species harvested by local communities. With global warming, sea ice losses will result in substantial changes to Beaufort food web production, with the consequences for benthic and pelagic foodwebs being unknown. Oil and gas exploration will further impact the nearshore portions of the foodweb. Coupled, these changes recommend a detailed assessment of anthropogenic impacts on Beaufort nearshore foodwebs and the anadromous fish species that rely on them. Component 4 focuses on the effects of climate change on Arctic charr subsistence resource in the Inuvialuit Settlement Region. Climate changes have already been observed in many parts of the Canadian North including higher than average annual temperatures, changes in lake ice thickness, melting permafrost, and the shortening of ice cover periods on lakes (Wrona et al. 2006). It is hypothesized that these climate changes will lead to indirect secondary effects on Arctic freshwater and anadromous fishes, resulting in changes to body condition and growth, changes in anadromous behaviours, and losses of local biodiversity due to alterations to habitat (Reist et al. 2006a). The people in the local communities will have to adapt to the potential outcomes of these secondary effects. However, there is a general lack of long-term environmental and faunal data for many of the northern regions of Canada, including the Inuvialuit Settlement Region (ISR) (Reist et al. 2006a), and therefore, a lack of understanding of how the changing climate will ultimately affect northern species. This component of the research focuses on studying the effects of the local environment on Arctic charr growth using both scientific and Indigenous Knowledge in a mixed methods approach. The current importance of Arctic charr to Inuvialuit communities (Usher 2002) and the impending effects of a changing environment necessitate effective long-term community-based monitoring (CBM) plans. CBM supports opportunities for both local study and the collection of scientific data to inform the ongoing inquiry into how environmental stressors affect northern fish species.

ACTIVITIES

1) • What: Completion of analysis of stable isotope and THg data assembled for archival Arctic charr sample (n=300) captured from Heintzleman Lake with data used to examine hypotheses related to the influence of growth dilution, age, size, feeding habitats and maturity status on recorded tissue THg levels. Paper written and submitted.

• Where: All work completed in 2011, completed in laboratory settings in DFO Winnipeg (archival sample dissection), Environment Canada, Burlington (THg analysis) and the University of Waterloo (stable isotope and statistical analysis).

• When: Analysis completed January 2011 through November 2011.

• Who: MSc student S. Dorn (now van der Velden), Dr. M. Power and co-authors J. D. Reist and J. Babaluk from Fisheries and Oceans Canada, Winnipeg.

• How: Sample analysis for THg completed via thermal decomposition and atomic absorption spectroscopy following U.S. EPA method 7473 (U.S. Environmental Protection Agency 2007) using a Milestone Direct Mercury Analyzer (DMA-80) at Environment Canada Laboratories in Burlington, Ontario. Sample analysis for stable isotopes completed via tissue excising of archive fillets in DDO facilities in Winnipeg and mass spectrometry analysis at the Environmental Isotope Laboratory at the University of Waterloo.
using a A Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba elemental analyzer (Carbo-Erba, Milan, Italy).

2) • What: Completion of all stable isotope and THg analysis for Arctic charr from paired lacustrine and anadromous sample sites along a latitudinal gradient from Ellesmere Island to southern Quebec. Data used to test the following hypotheses: [1] anadromous Arctic charr have lower THg than conspecifics from closely located or sympatric non-anadromous populations, and this difference is consistent across a range of latitudes in eastern Canada, [2] within-population differences in THg are related to individual size, age, somatic growth rate, δ¹⁵N-inferred trophic level, and δ¹³C-inferred carbon source, and the relationships are similar among anadromous and non-anadromous populations, and [3] among-population differences in mean THg are similarly related to differences in mean size, age, trophic position, and somatic growth rate. Paper written and submitted.

• Where: Analysis of previously obtained (2010) samples completed at Environment Canada, Burlington (THg analysis) and the University of Waterloo (stable isotope and statistical analysis).

• When: January 2011 through December 2011.

• Who: MSc students S. Dorn (now van der Velden) and co-authors.

• How: Sample analysis for THg completed via thermal decomposition and atomic absorption spectroscopy following U.S. EPA method 7473 (U.S. Environmental Protection Agency 2007) using a Milestone Direct Mercury Analyzer (DMA-80) at Environment Canada Laboratories in Burlington, Ontario. Sample analysis for stable isotopes completed via tissue excising of archive fillets in DDO facilities in Winnipeg and mass spectrometry analysis at the Environmental Isotope Laboratory at the University of Waterloo using a A Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba elemental analyzer (Carbo-Erba, Milan, Italy).

3) • What: Continued PIT-tagging of Nepihjee River Arctic charr population and re-capture of previously tagged fish and expansion of the project to include use of acoustic tags for monitoring the marine phase of the life-history.

• Where: Field site on the Nepihjee River and Gilbert Bay, Labrador.

• When: August to September 2011.

• Who: Nunavik Research fisheries biologist D. Campbell and Corey Morris, DFO

• How: Via live capture of Arctic charr in a special purpose live trap inserted into a fishway and use of standard PIT-tagging equipment. For the acoustic tagging we have negotiated use of an existing array of receivers in place in Gilbert Bay. The array was put in place by DFO to monitor Atlantic salmon and cod, but the existence of co-occurring Arctic charr has enabled us to collect data from Arctic charr without having to invest to receiver infrastructure, which is expensive. By establishing a partnership with DFO we will be able to increase the number of fish tagged and the data collected. To date all relevant study design details have been completed and tags ordered. Tags will be implanted starting in the spring of 2012.
never analysed. Paper partially written and will be ready for submission in March of 2012.

- Where: All statistical analysis for growth comparisons completed at the University of Waterloo. Analysis of within season growth data ongoing.
- When: January to December 2011 and ongoing.
- Who: MSc student A. Murdoch.
- How: Statistical regression and other analyses.

5) • What: Use of archival tissue samples of the fish community of the Nepihjee system’s major lake to assess the ecological impact of the introduction of Arctic charr into the system. Specifically data were used to compare food web structure in a resource-limited sub-Arctic lake before and after the introduction of an anadromous Arctic charr population to determine whether there have been significant alterations in food web structure. Paper written and submitted.

- Where: Stable isotope analysis completed at the Environmental Isotope Laboratory at the University of Waterloo. All statistical analysis completed at the University of Waterloo.
- When January to December 2011.
- Who: MSc student A. Murdoch.
- How: Using a A Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba elemental analyzer (Carbo-Erba, Milan, Italy) with analysis of the data completed using standardized statistical test and foodweb metrics as proposed in the literature (e.g. Layman et al. 2007).

6) • What: Use of archival tissue samples of Dolly Varden charr to construct a spatial and temporal baseline dataset on THg contamination in Dolly Varden charr for the Yukon Territory.

- Where: Dolly Varden charr samples obtained from archival storage at DFO Winnipeg. Stable isotope and THg analyses completed on available in-house facilities at the University of Waterloo.
- When May to December 2011.
- Who: MSc student L. Tran.
- How: Sample analysis for THg completed via thermal decomposition and atomic absorption spectroscopy following U.S. EPA method 7473 (U.S. Environmental Protection Agency 2007) using a Milestone Direct Mercury Analyzer (DMA-80) at Environment Canada Laboratories in Burlington, Ontario. Sample analysis for stable isotopes completed via tissue excising of archive fillets in DDO facilities in Winnipeg and mass spectrometry analysis at the Environmental Isotope Laboratory at the University of Waterloo using a A Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba elemental analyzer (Carbo-Erba, Milan, Italy).

7) • What: Continued characterization of the variation in immunological responsiveness of Arctic charr using previously obtained field and archival samples. The purpose of this study is therefore, to evaluate differences in MH constitution along a latitudinal gradient in order to better understand the relationship between pathogen load, the local environment and the function of the immune system both within and between individuals of a northern cold water fish species.

- Where: University of Waterloo laboratories.
- When: All of 2011 and on-going.
- Who: PhD student T. Robinson.
- How: Using state-of-the-art genotyping methods (MH) as described in the methods of DNA extraction and genotyping described by Conjeros et al. (2008).
8) • What: Commencement of stable isotope analysis to characterize marine trophic position and variability within and among exploited DVC populations and expansion of the analysis to include other anadromous fish stocks (e.g., broad white fish, cisco) will allow the position and role of DVC in nearshore foodwebs to be precisely defined. To date 300 sample shave been analysed, with another 500-600 possible. Research here will integrate with BREA iniatives in the Beaufort Sea to ensure complementary analyses are completed. Existing assessments of the nearshore Beaufort Sea have demonstrated the importance of terrestrially-derived carbon for nearshore marine biota, with the distinctive isotopic signatures of terrestrial and marine source materials allowing detection and quantification of the source fractions in the tissues of Beaufort nearshore foodweb fauna that permit estimating the relative importance of benthic or pelagic processes for supporting DVC and/or its overall productive potential. Results of the analysis will be contrasted with IPY-related studies of anadromous Arctic charr in the eastern Arctic as a means of enhancing overall understanding of the trophic position and role of charrs in the marine environment.

• Where: DO laboratories in Winnipeg and University of Waterloo laboratories.

• When: All of 2011 and on-going.

• Who: Power, Reist and hired BSc laboratory technician K. Mitchell.

• How: Tissues for study culled from archival and current DFO sampling programs on-going in the Beaufort Sea. All stable isotope analysis completed at the University of Waterloo using a A Delta Plus Continuous Flow Stable Isotope Ratio Mass Spectrometer (Thermo Finnigan, Bremen, Germany) coupled to a Carlo Erba elemental analyzer (Carbo-Erba, Milan, Italy).

9) • What: Presentation of interim results to appropriate national and international conferences.

• Where: Arctic Monitoring and Assessment Programme (AMAP) conference. The Arctic as a Messenger for Global Processes; Climate Change and Pollution. Copenhagen, Denmark.

• When: May 2011, June 2010 and December 2010:


• How: Platform and poster presentations as follows:


• Gantner, N., Muir, D., Power, M., Pienitz, R., Hintelmann, H., Meili, M. and Reist, J. Variations of mercury stable isotope fractionation and mercury transfer in food webs of lakes with Arctic charr (Salvelinus alpines L.) in the Canadian Arctic. Arctic Monitoring and Assessment Programme (AMAP) conference. The Arctic as a Messenger for Global Processes; Climate Change and Pollution. May 3-6, 2011. Copenhagen, Denmark.

• Nielsen, A. B., Svenning, M.-A., Power, M. and Christoff ersen, K. S. Aquatic ecosystem climate revealed from retrospective otolith analysis from Arctic charr (Salvelinus alpinus L.) from N. E. Greenland. Arctic Monitoring and Assessment Programme (AMAP) conference. The Arctic as a Messenger for Global Processes; Climate Change and Pollution. May 3-6, 2011. Copenhagen, Denmark.

• What: Field sampling for lake habitat characteristics including zooplankton, bathymetry, water quality and shoreline integrity.
• Where: The Sachs Harbour, Banks Island NT study sites include Fish, Middle, Capron, Kuptan, and Raddi lakes. Field sampling at Ikahavik Lake could not be completed this year due to poor weather and flight logistic issues.
• When: July-August 2011 (6 weeks)
• Who: PhD Candidate J.Knopp, field assistant and HQP D. de Kerckhove and local field assistants T. Lucas and K. Gully.
• How: Using a zodiac boat, horizontal plankton tows were completed to collect zooplankton, water quality samples were collected and sent to a lab for analyses of a suite of parameters, GPS-linked depths were recorded across lakes transects to collect bathymetry data and photographs for quantification of shoreline integrity were documented. This data collected was analyzed back in the lab.

11)  
• What: Arctic charr sampling.
• Where: The Sachs Harbour, Banks Island NT study sites include Fish, Middle, Capron, Kuptan, and Raddi lakes. Field sampling at Ikahavik Lake could not be completed this year due to poor weather and flight logistic issues.
• When: July-August 2011 (6 weeks)
• Who: PhD Candidate J.Knopp, field assistant and HQP D. de Kerckhove and local field assistants T. Lucas and K. Gully.
• How: Using a zodiac boat and multimesh gillnets, fish were captured, euthanized and sampled for length, weight, age, sex, maturity, stomach contents, parasite load, gonad weight, otolith and tissue collection.

12)  
• What: Training of local residents in Arctic charr scientific sampling methods.
• Where: The Sachs Harbour, Banks Island NT study sites include Fish, Middle, Capron, Kuptan, and Raddi lakes. Field sampling at Ikahavik Lake could not be completed this year due to poor weather and flight logistic issues.
• When: July-August 2011 (6 weeks)
• Who: PhD Candidate J.Knopp, field assistant and HQP D. de Kerckhove and local field assistants T. Lucas and K. Gully.

13)  
• What: Ulukhaktok Traditional Knowledge interview analyses.
• Where: Trent University
• When: 2011-2012
• Who: PhD Candidate J.Knopp
• How: Thematic coding and NVivo analysis of TK interviews. Verification could not be completed with the community of Ulukhaktok this year due to poor weather and flight logistic issues. The community could not be visited but rescheduling of the verification meeting is planned for February 2012.

14)  
• What: Arctic charr tissue analysis for mercury levels.
• Where: Trent University, Peterborough ON
• When: Jan. – Mar. 2012
• Who: Hogler Hintelmann lab, Trent University
• How: Requests from the community for the charr monitoring plan included the monitoring of con-
taminants in charr, specifically mercury levels in lake fish to provide current baseline information on the status of mercury levels in these fish.

15)
- **What:** TK database creation.
- **Where:** Trent University, Peterborough ON
- **When:** 2011-2013, on-going
- **Who:** J.Knopp and M. Toll
- **How:** A database of Traditional Knowledge and local expert information on Arctic charr was requested by the FJMC at the beginning of the project. TK interview participant spatial data was imported into a GIS database for the project. All data points from the Sachs Harbour participant mapping from the TK interviews have been entered into the database. The corresponding information for each geographical location as shared in the interviews is being entered into the database. Work is underway to add the Ulukhaktok participant mapping and TK interview to the database.

16)
- **What:** Data analyses of collected field data
- **Where:** Trent University, Peterborough ON
- **When:** 2011-2013, on-going
- **Who:** J. Knopp
- **How:** Charr ageing, age-specific otolith back-calculation for growth determination, ArcGIS bathymetry analyses, shoreline integrity, zooplankton and water chemistry lab work and data analyses

17)
- **What:** Presentations and publications
- **Where:** American Fisheries Society Conference, Alaska Sea Grant Fishing People of the North International Symposium, NHEAR National Gathering of Graduate Students,


Café, Calgary Alberta. Invited Panel Speaker to discuss PhD research project and the future of Arctic Science, May 2011.
RESULTS

A sample of Arctic charr from Heintzelman Lake (81°42’N, 66°56’W), Ellesmere Island, was used to elucidate the biological and life-history factors potentially influencing individual total mercury THg concentrations. Specifically, samples were used to test the hypotheses that: [1] life-history strategy predicts THg concentration, with lower concentrations in anadromous than non-anadromous Arctic charr at similar sizes and ages; [2] among non-anadromous individuals, fast-growing fish have lower THg concentrations than slow growing conspecifics (i.e., growth dilution explains the pattern of among individual differences); [3] differences in prey resource use identified by gut content and stable isotope analyses are correlated with differences in THg concentration; and [4] fish that allocate more energy to reproduction have lower somatic growth rates, and higher total mercury concentrations. Migratory history was significant, with anadromous fish having a lower mean THg concentration (63.8 μg/kg) than non-anadromous Arctic charr (117.1 μg/kg net weight). The accumulation of mercury with exposure time (age) was shown to be independent of growth rate when large and small individuals within the same age groups were compared, providing no support for the growth dilution hypothesis. Similarly, the diets of individual Arctic charr were comparable regardless of size and growth rate, and there was no apparent shift in diet with increasing size that could explain differences in somatic growth rate or THg concentration among fast- and slow-growing groups of fish. Maturity state was also not related to THg concentration, but appears to be driving differences in somatic growth rate. Slow-growing fish allocated more energy to reproduction than did fast-growing conspecifics. It is postulated that the differences in THg concentration among individual Arctic charr are driven primarily by age (Figure 1). The accumulation of mercury with age can be altered by a shift in diet (e.g., to piscivory) or habitat (e.g., anadromy), but is not otherwise affected by changes in size or growth rate.

![Figure 1. Relationship between ln age (years) and ln total mercury concentration (THg μg/kg wet weight) for Arctic charr from the fast and slow growth groups sampled in Heintzelman Lake, Ellesmere Island. As there was no significant difference in the age-mercury relationship between the two groups (ANCOVA P > 0.05), a common slope regression line was estimated using the data from both groups. Modified from van der Velden et al. 2012](image)

Results of paired population (lacustrine versus anadromous) Arctic charr along a latitudinal gradient from Ellesmere Island to southern Quebec have yield similar results to the detailed Heintzelman Lake study. Anadromous Arctic charr had THg ranging from 9.0 to 216.8 ng/g wet weight, while the concentrations in non-anadromous fish ranged from 27.9 to 1033.0 ng/g wet weight. Only 2 of the 582 individuals analyzed had THg greater than Health Canada’s 0.5 μg/g wet weight (500 ng/g wet weight) limit for mercury concentration in commercially sold fish, and both were non-anadromous. The THg of 40 individuals exceeded the 0.2 μg/g wet weight guideline for frequent fish consumers. Of these, 38 fish were non-anadromous and 2 fish were anadromous. Within-population mean THg ranged from 19.9 to 113.6 ng/g wet weight in anadromous populations, and from 111.1 to 226.5 ng/g wet weight in non-anadromous populations. The non-anadromous populations had mean THg 1.8 to 6.3 times higher than paired anadromous populations, and there was a significant difference in ln THg for each pair (two-sample t-tests; all p < 0.01; Figure 2). Within-population ln THg was positively related to
both fish age and fork-length. Significant positive relationships between age and ln THg occurred in 6 of 9 anadromous (linear regression; mean $R^2 = 0.44$) and 7 of 9 non-anadromous (mean $R^2 = 0.56$) populations. Partial correlation analysis revealed that fish age was a better predictor of within-population ln THg than fork-length. Little evidence was found to support a growth dilution effect on Arctic charr THg, either within or among populations and life-history types. While there was a wide range in age-specific fork-length (i.e., average growth rate) among populations of both life-history types, there was no relationship to age-specific ln THg in either the anadromous or non-anadromous populations.

PIT-tagging studies on the Nepihjee continued to yield good data on the period of marine residency of Arctic charr from the Ungava region of Quebec. Some Arctic charr (238 fish) were counted ascending the Nepihjee fishway, of which 75 had been previously PIT-tagged and for which annual incremental growth information could be computed. Peak count of 39 fish occurred on August 15. The addition of these individuals significantly expended the dataset available for the comparative growth study reported on below. In addition to the Arctic charr, 15 white fish (*Prosopium cylindraceum*) and a single brook charr (*Salvelinus fontinalis*) ascended the fishway. Count results were considered good in light of persistent problems with high water which delayed the installation of the counting fence on the river and hampered operation. Anecdotal evidence suggests that in highwater years fish are able to ascend the waterfall on the Nepihjee at multiple points, thereby bypassing the trap. Accordingly, the count for 2011 is considered to be biased on the low side.

As the majority of studies investigating temperature-growth relationships in Arctic charr have been limited to laboratory situations, similar work in the natural environment where food availability fluctuates is lacking. And there is a particular shortage of temperature-
growth research on adult Arctic charr during the period of marine residency, especially in northern Canada. To correct the data deficiency, PIT-tagging experiments were carried 2009-11 out in the Nepihjee River, near Dry Bay, Ungava Bay, Québec (58°32’N, 68°15’W) and results were compared to data obtained from earlier 1981-84 experiments in the Ikarut River, Hebron Fiord, Labrador (58°12’N, 62°31’W). Growth rate (length-at-recapture minus length-at-tagging-capture) comparisons indicated significant differences between sites, with the annual mean growth rate ±1SD estimated for Hebron Arctic charr (19±12mm/year) being less than for Dry Bay Arctic charr (89±14mm/year). For the period Hebron region mean sea surface temperatures (SSTs) ranged from 0.9-1.7°C, but there was no effect on achieved mean annual growth rate. Based on the NOAA-derived data, these temperatures were all below the long-term SST summer mean (1971-2000) for the region (1.9°C). In contrast, Dry Bay SSTs for the 2020 and 2011 summers for which growth data are available were, respectively, 3.0-3.3°C, well above the long-term SST summer mean (1971-2000) for the Dry Bay region. Similarly, there was no significant difference in realized mean annual growth rate.

In concert with the operation of the fishway, an analysis of the ecological impacts of the introduction of Arctic charr into the Nepihjee River was completed by assessing shifts in the fish community foodweb structure of the largest upstream lake (Lake Qamutissait 58°24’N 68°23’W) used for over-wintering purposes. The Nepihjee watershed was a system previously uninhabited by Arctic charr due to the presence of an impassable waterfall located approximately 500m upstream from the river mouth. In 1999, the introduction of Arctic charr was facilitated by the construction of a naturalized 2m wide, 1m deep and 70m long channel (fishway) bypassing the falls, and via stocking efforts from a Kuujjuaq-based hatchery. Between 2000 and 2010, approximately 75,000 locally raised hatchery fry were released annually into the Nepihjee watershed. Annual August-September monitoring of the fishway subsequent to 1999 has demonstrated that Arctic charr have successfully moved through the fishway and into the watershed for overwintering, with annual counts ranging from 200-1000 individuals. Incidental winter sport fishery activity by local residents has further demonstrated winter occupancy by Arctic charr of the lower of three lakes within the Nepihjee watershed. The ecological consequences of such introductions in northern sub-Arctic aquatic ecosystems are not known. To assess possible impacts, food web structure was compared using samples obtained before (1999) and after the introduction (2007 and 2010) of anadromous Arctic charr population to determine whether there have been significant alterations in food web structure. Results showed baseline invertebrate isotope ratios did not differ pre- and post-introduction. Although annual mean carbon and nitrogen isotope signatures for the fish community revealed some significant shifts by year, patterns relative to the presence or absence of Arctic charr were lacking. Examination of the isotope values of the dominant predator, lake trout Salvelinus namaycush, showed no significant changes in either the isotope signatures or the net tendency of the trout to rely on energy derived from the pelagic or littoral food web chains within the lake. When aggregated together into community wide metrics (e.g. Layman et al. 2007), some minor shifts in food web structure were observed. For the most part observed changes in quantitative food web metrics were not statistically significant when comparing pre- and post-introduction time periods. Thus the introduction of Arctic charr to Lake Qamutissait generally had no effect on the measured isotopic ratios of resident fish species or associated food web metrics.

Mercury levels in northern aquatic ecosystems are of particular concern because of potential bioaccumulation impacts on human populations, including the Gwich’in and the Inuvialuit, that rely on fish as a key component of their diet (Lockhart et al. 1998). Further compounding existing concerns for Hg accumulation in aquatic ecosystems are the potential impacts of climate change. While numerous studies have documented THg levels in other fish (e.g., Arctic charr, northern pike, broad whitefish, walleye, inconnu and lake trout (Stewart et al. 2003, Evans et al. 2005b, Lockhart et al. 2005, Muir et al. 2005, Ganter et al. 2010b)), knowledge of Dolly Varden contamination levels remains anecdotal with Dolly Varden charr contamination levels typi-
cally reported as incidental values in larger fish studies (e.g. Lockhart et al. 2005). For example searches of scientific databases (ISI Web of Science) yielded only a single primary scientific literature reference to mercury levels in DVC. Furthermore, routine assessment of mercury levels in DVC has not been included in the Northern Contaminants Programme or the Arctic Monitoring and Assessment Programme or associated reports. Thus spatial and temporal data for populations of Canadian concern (e.g. Firth, Rat & Babbage Rivers) are clearly lacking. In view of the importance of Dolly Varden charr as a source of dietary protein (Daviglus et al. 2002), the increasing concerns for changes in mercury accumulation rates as a result of predicted climate change (Macdonald et al. 2005) and the fact that so little information exists on mercury in DVC, we obtained archived DVC tissue samples through DFO (1986 on) to construct spatial and temporal profiles of total mercury (THg) in DVC for relevant populations of concern in the Yukon. The samples have been analysed as a key step in improving the existing data and understanding of THg levels in DVC. To date 517 samples have been analysed from nine different sites from throughout the Yukon. Samples were sub-selected from the DFO archive to account for variability within- and among-populations. Obtained THg data have further been combined with age, length, life-history type and trophic position information derived from parallel stable isotope analyses to determine: [1] whether there is statistical evidence for an increasing temporal trend in DVC THg contamination within the Yukon, [2] which associated biological factors (e.g., length, age, trophic position) best explain observed variability in THg tissue concentrations in DVC, and, [3] whether life-history type (e.g. isolate versus anadromous) influences THg levels. Data for THg from the analyses are presented in Table 1. Stable isotope analyses have been completed, with values currently under-going QA/QC. Statistical analysis of the data to assess the quantitative support for the suggested hypotheses will begin once the stable isotope data have been vetted.

Table 1: List of sampling sites for which samples of Dolly Varden charr have been obtained and analysed. Number and year of sampling, sample site geographic co-ordinates, life-history type, and mean THg [ng/g] ± standard error are given. Anadromous fish are those completing part of their life cycle in the Beaufort Sea. Isolates fish are those that do not migrate from their natal river owing to migratory barriers.

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>n</th>
<th>Year sampled</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Life-history type</th>
<th>Mean THg [ng/g] ± Std Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pauline Cove</td>
<td>30</td>
<td>1989</td>
<td>69°34′47″N</td>
<td>138°52′12″W</td>
<td>Anadromous</td>
<td>79.6 ± 9.0</td>
</tr>
<tr>
<td>Thetis Bay</td>
<td>8</td>
<td>1989</td>
<td>69°32′59″N</td>
<td>139°01′48″W</td>
<td>Anadromous</td>
<td>82.3 ± 16.1</td>
</tr>
<tr>
<td>Ptarmigan Bay</td>
<td>30</td>
<td>1988</td>
<td>69°29′11″N</td>
<td>139°01′12″W</td>
<td>Anadromous</td>
<td>28.9 ± 1.2</td>
</tr>
<tr>
<td>Shingle Point</td>
<td>16</td>
<td>1989</td>
<td>68°58′48″N</td>
<td>137°31′12″W</td>
<td>Anadromous</td>
<td>70.6 ± 11.6</td>
</tr>
<tr>
<td>Babbage River</td>
<td>30</td>
<td>1991</td>
<td>68°37′47″N</td>
<td>139°22′12″W</td>
<td>Anadromous</td>
<td>105.6 ± 6.9</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>1988</td>
<td></td>
<td></td>
<td></td>
<td>29.0 ± 6.4</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1991</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>105.6 ± 6.9</td>
</tr>
<tr>
<td>Firth River</td>
<td>30</td>
<td>1988</td>
<td>68°40′12″N</td>
<td>140°55′11″W</td>
<td>Anadromous</td>
<td>98.1 ± 12.2</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1986</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>110.5 ± 6.8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1988</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>98.1 ± 12.2</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1995</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>129.4 ± 7.4</td>
</tr>
<tr>
<td>Canoe Creek</td>
<td>30</td>
<td>1988</td>
<td>68°46′11″N</td>
<td>138°45′00″W</td>
<td>Anadromous</td>
<td>45.0 ± 2.0</td>
</tr>
<tr>
<td>Cache Creek</td>
<td>30</td>
<td>1988</td>
<td>68°31′11″N</td>
<td>136°13′47″W</td>
<td>Anadromous</td>
<td>63.1 ± 2.5</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>1988</td>
<td></td>
<td></td>
<td>Isolates</td>
<td>31.2 ± 1.7</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1988</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>63.0 ± 2.8</td>
</tr>
<tr>
<td>Rat River</td>
<td>30</td>
<td>1988</td>
<td>67°46′48″N</td>
<td>136°19′11″W</td>
<td>Anadromous</td>
<td>83.2 ± 7.8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1986</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>80.9 ± 9.2</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1988</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>83.2 ± 7.2</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1995</td>
<td></td>
<td></td>
<td>Anadromous</td>
<td>76.8 ± 5.2</td>
</tr>
</tbody>
</table>
Water quality sampling and fish habitat characterization was conducted to provide a whole-ecosystem overview of the sampling lakes. This data helps to provide a clear picture of potential differences between lake characteristics and fish habitat to allow for an accurate comparison of charr growth, and the regional effects on growth, across all lakes in the study. Parallel increases or decreases in charr growth in a given year across all study lakes, despite similarities or differences in lake habitat conditions, would indicate a regional rather than a lake-specific phenomenon. Anomalous climate conditions in that year may be an indicator of the link between climate and fish growth. The preliminary results of the quantitative analyses of scientific data showed differences in water chemistry, percent bank erosion, and lake volume and depth among the five sample lakes near Sachs Harbour. Arctic charr diet and parasite load varied among the six study lakes as well. The von Bertalanffy growth curves compiled from otoliths collected in 1993-94 by Fisheries and Oceans Canada showed the populations in four lakes fit expected growth patterns, but these study lakes which are in close proximity to one another showed differences among all four populations in the maximum size attained by the charr and the age at which the maximum size for that lake was reached. This demonstrates that lake environment does have an effect on Arctic charr growth. However, the preliminary results of the otolith back-calculation for charr captured in 2008-2009 show a large increase in growth in a single calendar year across a range of age classes in both Middle and Capron lakes. This would then demonstrate that despite variations in lake environments among the five study lakes, a local environmental condition(s) is affecting charr growth consistently across the study lakes. The environmental parameters determined through both the ecological and local expert Indigenous Knowledge are currently being analyzed in association with this year of observed increased growth in order to test linkages between growth and climate.

**DISCUSSION**

Observed non-anadromous Arctic charr THg levels (mean = 0.117 mg/kg) in Heintzelman Lake Arctic charr generally fell within the ranges of THg concentrations reported for landlocked Arctic charr from other Arctic lakes (e.g. Gantner et al. 2010a,b, Evans et al. 2005a). Arctic charr captured from Heintzelman Lake also demonstrated a life-history effect on measured THg concentrations consistent with other studies (Evans et al. 2005), with non-anadromous individuals having higher concentrations than anadromous conspecifics. Examination of selected groups of slow and fast-growing fish provided no support for the growth dilution as a mechanism for explaining observed differences, as both groups had statistically similar THg concentrations at a common age. Furthermore, minor differences in feeding strategy also failed to explain the observed differences. Although maturity state was not related to THg concentration, a larger proportion of ripening fish was associated with lower somatic growth rates. The observed differences in size and growth rate among individual Arctic charr in Heintzelman Lake appear to be driven by differential maturation schedules, with the slow-growing fish devoting more energy to reproduction than the fast-growing fish. This is evidenced by a larger proportion of ripening fish, as well as a higher gonadosomatic index, in the slow-growing group. Parker and Johnson (1991) similarly noted from studies of other Ellesmere Island lakes that smaller Arctic charr mature earlier. Indeed, there is a general tendency for smaller, often “dwarf,” Arctic charr to mature at an earlier age than larger conspecifics (e.g. Klemetsen et al. 2003, Power et al. 2009). Because Arctic charr display large variations in growth rate and size at maturity (Parker and Johnson 1991, Klemetsen et al. 2003), and often display bimodal size distributions or “standing waves” in length-frequency distributions (Power et al. 2008), Arctic charr of the same size can be of very different ages. As predicted by fish ages, fast-growing individuals had lower THg concentrations than slow-growers at a given size, and the disparity increased with increasing fork-length. Accordingly, it is recommended that ages be determined whenever mercury concentrations in fish are examined.

Evidence from the latitudinal gradient study provided support for the hypothesis that anadromous Arctic charr have lower THg than non-anadromous conspecifics.
across a range of latitudes in eastern Canada, but the difference in THg between the life-history types was variable. Mercury concentrations in both life-history types were most consistently related to fish age, though significant positive relationships with fork-length and d15N inferred trophic position also occurred. Differences in d13C were poorly related to THg in both anadromous and non-anadromous Arctic charr. Among-population differences in mean THg were not related to differences in mean size, age, trophic position, or somatic growth rate. A considerable portion of the variability in THg among sampling locations remains unexplained by fish characteristics (age, size, trophic position). There was a modest trend of increasing mercury with latitude among Arctic charr of both life-history types. Fish age was the most consistent predictor of THg within both anadromous and non-anadromous Arctic charr, although significant relationships between age and THg did not always occur. Our findings agree with previous studies that have found age to be a better predictor of THg than size in Arctic charr (Rognerud et al. 2002, Swanson and Kidd 2010, Swanson et al. 2011) and other northern fish species (Evans et al. 2005b). Latitude was positively linked to [THg] in both anadromous and non-anadromous Arctic charr when the significant effects of age, fork-length, and trophic offset were accounted for. This is despite trends of mercury in lake sediments, indicating a decrease in Hg deposition from south to north (Muir et al. 2009, Schindler et al. 1995). Evans et al. (2005b) also found that fish [THg] increased with increasing latitude, though fish from more northerly lakes were also older. Here the relationship with latitude exists when the variability due to age is accounted for, indicating a separate effect of latitude. The positive trend with latitude observed here may reflect a more efficient transfer of Hg through the foodweb at northern locations (Schindler et al. 1995).

Operation of the Nepihjee fishway continued to yield quality data useful for studying the marine portion of the life-history in Arctic charr. Count results were considered good in light of persistent problems with high water which delayed the installation of the counting fence on the river and hampered operation. For example, during the period August 18-21 high water prevented trap access and continued weather problems forced early closure of the fence. Nevertheless valuable additional growth information was obtained and was used in the analysis discussed below.

Our studies have demonstrated for the Canadian Arctic charr the effects of sea temperature and days at sea variably influenced in-situ growth. Growth-temperature comparisons between two regions, Hebron Fiord, Labrador and Dry Bay, Ungava Bay, yielded evidence of conditional temperature effects on growth. Contrary to predictions, inter-annual growth among years did not change in the Hebron Fiord region despite Arctic charr experiencing increased mean temperatures in a number of the study years. However, when compared across sites a comparatively small increase in mean temperature (approximate 2° C) at Dry Bay yielded a four-fold increase in growth in comparison to Hebron Bay. Differences in the observed temperature-growth relationship for Arctic charr within and between sites may be related to differences in regional food availability. Local productivity (ration) is a major factor influencing growth-temperature relationships in fish, as demonstrated in laboratory studies of brown trout, Salmo trutta, growth as temperature and ration varied (Elliott 1994). Where ration is limited, the realized scope for growth is reduced and subsequent increases in temperature will further reduce achievable growth as metabolic maintenance demands rise with temperature (Elliott 1994). The null effect of increases in temperature on achieved growth in Hebron Arctic charr is suggestive of food limitations where increases in temperature are not matched by proportionate increases in energy availability. This interaction is exemplified elsewhere in nature, such as the importance of temperature, irradiance and nutrients driving marine primary productivity fluctuations (Dayton et al. 1994). Coincident with warmer temperatures, productivity in Ungava Bay measured as chlorophyll a ranges between 1-1.5mg m-3 (median 1.4mg m-3) and exceeds values typically observed along the Labrador coast (0.4-0.6mg m-3) (Witman et al. 2008, Frajka-Williams and Rhines, 2010). Combined site-specific differences in productivity, temperature and observed growth suggest a mechanism whereby temperature driven increases in metabolic demand are
met with sufficient surplus energy to realize the temperature dependent scope for growth (Elliott 1994) in Ungava Arctic charr, but not in Hebron Arctic charr.

The analysis of the ecological impacts of the introduction of Arctic charr into the Nepihee River represents the first and only such study available for the North. Findings from this unusual occurrence of an authorized subarctic introduction can be used as a tool for determining the feasibility of future Arctic charr introductions in the North. The evidence here of an open niche available in a Subarctic lake suggests that anadromous Arctic charr may be added to similar watersheds without negative effects on resident fish community structure. Notably, even in Lake Qamutissait where the fish community is relatively developed for subarctic conditions, the impacts appeared minimal. This suggests that findings may be easily extensible to other Subarctic and Arctic lakes in equivalent or higher latitudes where fish communities are even simpler. However, effects on watersheds that are less productive or containing more complex species assemblages may be harder to predict, and must still be evaluated case by case. Other factors such as watershed size and proximity to source populations may also alter results. For example, in areas that are close to large established anadromous Arctic charr populations, newly opened lakes may receive high influxes of charr, potentially negatively affecting resident fish species. In this regard, the proximity of the Nepihee watershed to nearby overwintering sites (>50km, Barton et al., 1984) allows it to be a more conservative case, and may explain why fairly low sustainable numbers of migrating Arctic charr have been reported to-date. Finally, fisheries management should prioritize Arctic charr habitat remediation for established populations before undergoing major projects such as facilitating introductions, as exemplified by the Arctic charr Stream Enhancement Project (ACSEP) which has been ongoing in Nunavik since the late 1980’s (Mesher 1999, Mesher 2001, Mesher 2003, Chum 2005, Chum 2006). Arctic charr have reportedly had difficulty ascending 40% of rivers that were traditionally fished in the Ungava Bay basin (Power and Barton 1987), and the implementation of ACSEP has facilitated many small-scale remedial works with the goal of mitigating these stream obstructions. Only in exceptional cases, the Nepihee being a primary example where the payoff for removing a single barrier was quite high, will an introduction be a viable undertaking for a community.

On-going statistical analysis for the Dolly Varden charr THg analysis, the MH genetic analysis and the commencement of analysis to characterize marine trophic position and variability within and among exploited DVC populations in the Beaufort currently precludes making interpretative comment on existing results, although on-going analysis should permit comment by this time next year.

To date the project has developed a more comprehensive understanding of the local lake ecosystems and identification of environmental factors influencing charr growth in this region than previously existed. This resulted from the linking of scientific quantitative datasets with qualitative data gathered from local experts and IK holders. The iterative process used to bring together both the qualitative and quantitative data through the course of the project, using a concurrent parallel mixed-methods design with triangulation, is developing a more holistic approach to the study and identification of environmental parameters that could affect charr growth. For example, the Indigenous Knowledge interviews indicated that annual sea-ice coverage in the areas surrounding Banks Island have an effect on the local lake conditions. The preliminary results of the quantitative analyses show concordance with the Indigenous Knowledge and community observations of recent changes. Many more areas of agreement between the two knowledge bases are being identified in the ongoing analysis in this project. The analysis and interpretation of data from this project is ongoing.

**CONCLUSION**

Work at Heintzelman Lake demonstrated a life-history effect on measured THg concentrations, with non-anadromous individuals having higher concentrations than anadromous conspecifics. Examination of selected...
groups of slow and fast-growing fish provided no support for the growth dilution hypothesis, as both groups had statistically similar THg concentrations at a common age. A key contribution of the Heintzelman study is the demonstration that in populations of fish that display only subtle variations in feeding strategy (i.e., where consumption opportunities are restricted), it is exposure time and not size that determines fish mercury concentration. Studies of temperature-growth relationships completed as part of ArcticNet funded research activities have indicated regional sensitivities to temperature fluctuations. Knowledge of individual growth and temperature regimes as well as information regarding local food availability, therefore, are necessary for determining accurate portrayals of this complex relationship. High-latitude species such as the Arctic charr are considered especially vulnerable to climate change effects due to the accelerated climatic change of this region, and results here suggest that future increases in water temperature may have profound consequences for Arctic charr growth depending on how climate-warming affects local productivity levels. Finally, assessment of the foodweb impacts of an anadromous Arctic charr indicated significant ecological impacts. The explanation for the lack of ecological impact due to the introduction was related to the availability of open ecological niches in the evolutionary young aquatic systems found in the North that allow Arctic charr to use resources which were previously unused by resident fish species. Findings from this study indicate that anadromous Arctic charr may be introduced to similar watersheds in the north without negative consequences for resident fish community structure, a fact that will facilitate the judicious management of the resource to meet the increasing demands for Arctic charr that will result from increased human populations.

The community members from Sachs Harbour have observed local environmental and climate variability and change including unpredictable and rapidly changing weather patterns, large increases in summer and winter ambient air temperatures, significant permafrost degradation and erosion, major changes to the local sea ice and water conditions including thinner sea ice in winter and a lack of icebergs in summer, changes to freshwater flow regimes, new species occurrences, and species not normally seen in this area showing up in higher numbers including belugas and salmon. It is crucial that monitoring of the Arctic charr resource occurs due to its importance to the Inuvialuit people and the increasingly dynamic nature of the environment in which they live. Ultimately, this information is needed to ensure the sustainability of the charr stocks being harvested by Inuvialuit communities. Further analyses of environmental conditions identified as affecting fish growth through such an approach as the mixed mixed-methods process used here will expand our understanding of local environmental indicators of change that are effective and feasible for use in Arctic charr community-based monitoring plans in these communities. The approach developed here, and lessons learned may be used as a model in other Arctic communities in the future.

The purpose of this project is to anticipate and demonstrate the secondary effects of climate variability on Arctic charr and provide understanding of these effects to the local resource users, allowing them to make informed choices about adapting to upcoming changes through community-based monitoring efforts. Key environmental and biological indicators of climate change effects on the growth of Arctic charr in Sachs Harbour will be used to forecast upcoming changes in charr growth. These environment indicators can then be used in Arctic charr community-based monitoring and fishing plans. This research provides the opportunity to exchange information and concepts of contemporary science and Inuvialuit Knowledge and to assist directly with the monitoring and management of local fish resources.

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• Members of the communities of Sachs Harbour and Ulukhaktok

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M. Power and C. Furgal


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