

The Effect of Anadromous Arctic Charr (*Salvelinus alpinus*) on Food Web Structure and Contaminant Concentrations in Coastal Arctic Lakes

by Heidi K. Swanson

EVERY SPRING, anadromous (sea-run) arctic charr (*Salvelinus alpinus*) hatch in freshwater lakes in the circumpolar North. In the West Kitikmeot region of Nunavut, the charr spend 3–8 years growing in these lakes before beginning annual migrations to the sea (Johnson, 1989). They feed in the sea for approximately 2–4 weeks before returning to freshwater to spawn or overwinter, or both (Johnson, 1989; Klemetsen et al., 2003). Arctic charr are both culturally and economically significant to Northerners and represented more than 40% of traditional-use species harvested in Nunavut between 1996 and 2001 (Nunavut Wildlife Management Board, 2004). They are also vulnerable to a variety of anthropogenic stressors, including climate change and industrial development. Climate-induced changes to migration routes are impacting sea-run arctic charr populations. Migrations are less successful in warm, dry years when flows in migratory streams are not high enough (Svenning and Gullestad, 2002), and increases in temperature can also have negative effects on stock size and recruitment (Power et al., 2000). Some northern communities have already noted climate-induced changes to migration habitat used by sea-run arctic charr and are attempting to restore and manage this habitat. For example, the community of Kugluktuk is currently documenting and teaching youth the history of a traditional fishing area near Bernard Harbour, and the community would like to examine the feasibility of restoring migration habitat for sea-run arctic charr in this area.

Despite the importance and high profile of sea-run arctic charr, various aspects of their ecology remain poorly understood. For instance, little is currently known about how sea-run arctic charr affect the structure and function of freshwater food webs. It appears that their presence may affect top-down or bottom-up changes in food web structure because they can function as both predator and prey in freshwater lakes. Fry and juveniles feed on freshwater invertebrates until the first sea migration, which usually occurs at three to eight years of age, but are also available as prey to resident piscivorous fish such as lake trout (*Salvelinus namaycush*). Once they reach sexual maturity, sea-run arctic charr do not usually feed in freshwater; however, they may require several sea migrations to reach sexual maturity, and until this happens, immature fish may feed in freshwater after their return from the sea in the fall (Rikardsen et al., 2003). This information indicates it is likely that lakes in the Canadian Arctic with sea-run arctic charr populations have different food web structures than those without this species. These differences, in turn, may affect contaminant concentrations.



Heidi Swanson with sea-run arctic charr (spawning male).

The accumulation of toxic contaminants in Arctic biota has been a concern for some time (e.g., Jensen et al., 1997). Many contaminants biomagnify up food webs to reach significant concentrations in top predator species. These high contaminant concentrations pose toxicity risks not only to wildlife, but also to local human populations. Northern residents can be exposed to relatively high concentrations of contaminants through consumption of traditional foods, such as fish and marine mammals (Oostdam et al., 2003). Although concentrations of some older, well-known contaminants such as PCBs seem to be decreasing in the Arctic (Jensen et al., 1997), many people are concerned about increasing concentrations of new contaminants such as polybrominated diphenyl ethers (PBDEs), used in flame retardants, and perfluorinated compounds (PFCs), used in stain repellents (e.g., de Wit et al., 2006; Environment Canada and Health Canada, 2006). The nearly ubiquitous presence of these new compounds throughout the Arctic can be attributed to a combination of local sources (e.g., PBDEs in air from trash incineration) and remote sources (brought by atmospheric or oceanic transport, or both) (Dinglasan et al., 2004; de Wit et al., 2006). Most of these new contaminants biomagnify (Giesy and Kannan, 2001; Van de Vijver et al., 2003).

Previous studies have shown that contaminant concentrations tend to be higher in fish from lakes with long food chains than in fish from lakes with short food chains (e.g., Kidd et al., 1998). To date, it is not known if the presence of juvenile arctic charr lengthens or shortens the food chain to other predatory fish (e.g., lake trout), or whether sea-run arctic charr occupy a higher or lower trophic position than other predatory fish species in freshwater



Marilynn Kullman, a field assistant, fishing at the mouth of the Nauyuk River.

lakes. However, it is likely that there are food web-induced differences in biomagnifying contaminant concentrations between lakes that do and do not support sea-run arctic charr populations.

My research questions are: 1) do sea-run arctic charr affect food web structure in coastal Arctic lakes; and, 2) do contaminant concentrations in traditional food fish species (e.g., lake trout and lake whitefish, *Coregonus clupeaformis*) differ between lakes that do and do not contain sea-run arctic charr, and can this difference be attributed to differences in food web structure?

BRIEF DESCRIPTION OF METHODS

Field Sampling and Laboratory Analyses

In summer 2006 and 2007, field research was performed on six lakes (three with sea-run arctic charr and three without) located near Hope Bay, Nunavut. Hope Bay is the site of an underground gold development and is approximately 110 km southwest of Cambridge Bay and 65 km east of Umingmaktok. Invertebrates (*Mysis relicta*, *Gammarus lacustris*, *Saduria entomon*), ninespine stickleback (*Pungitius pungitius*), cisco (*Coregonus* spp.), lake whitefish, and lake trout were collected from all six lakes, and arctic charr, from three lakes. Laboratory analyses for samples collected in 2006 are partially complete whereas samples collected in 2007 are currently being processed for analysis. All samples are being analyzed for stable carbon (C), nitrogen (N), and sulfur (S) isotopes to determine carbon source, trophic position, and anadromy, respectively. Concentrations of metals (including mercury) and organic contaminants (including PCB congeners and organochlorine pesticides, polybrominated flame retardants, and perfluorinated stain repellents) are also being determined in all samples. For fish that make annual migrations to the sea, microchemistry is being conducted



Heidi Swanson uses a "tundra buggy" to move gear between lakes.

on otoliths to determine age at first migration and frequency of migration.

Data Analyses

Differences in nitrogen sources between lakes can obscure differences in food web structure (e.g. Cabana and Rasmussen, 1996). To correct for this, invertebrates are being used to "normalize" the nitrogen isotope ratios found at the bottom of the food webs. Isotope ratios and contaminant concentrations from fish and invertebrates are also being adjusted for organism size prior to hypothesis testing. In addition to a number of exploratory analyses, I am testing the following null hypotheses: 1) there are no differences in species-specific trophic position between lake types (lakes with sea-run charr versus those without charr); and 2) there are no differences in species-specific contaminant concentrations between lake types. I am also examining migration patterns determined by otolith microchemistry and comparing them to previous records.

PRELIMINARY RESULTS AND DISCUSSION

Approximately half of the samples collected for this study have been analyzed; these represent one lake with sea-run arctic charr and three lakes without this species. During analyses of stable isotopes and otolith microchemistry, I found that there are sea-run lake trout in some of the study lakes, which complicates the analysis but is an interesting finding in itself. Although there has been anecdotal and limited scientific (see Martin and Olver, 1980) documentation of lake trout in coastal Arctic waters, it is generally thought of as a freshwater species. However, lake trout do have the ability to survive in saltwater (Hiroi and McCormick, 2007), and my preliminary results show that sea-run lake trout can be distinguished from their resident (no sea migration) counterparts by stable nitrogen, carbon, and



Morphs of lake trout captured in one of the study lakes.

sulfur isotopes, as well as by strontium concentrations in the otoliths (H. Swanson and K. Kidd, unpubl. data). These are the first isotopic or otolith microchemistry data that show this phenomenon. In addition, I observed a number of colour morphs of lake trout; further investigation is required to determine whether these morphs have different feeding strategies or habitat preferences, or both.

It appears that the presence of sea-run arctic charr in a lake may affect food web structure by providing an alternative prey source (juvenile arctic charr) for resident lake trout. Lake trout had a significantly lower trophic position (as determined by stable nitrogen isotopes) in the lake with sea-run arctic charr than in the lakes without sea-run arctic charr. These results are preliminary, but the data suggest that juvenile arctic charr serve as a high-quality, low-trophic position prey for resident lake trout. If lake trout from lakes with sea-run arctic charr have lower trophic positions, they may also have lower concentrations of biomagnifying contaminants. To date, I have data for only one contaminant, mercury, and these data are from a subset of lakes. It appears, however, that sea-run lake trout and arctic charr have lower concentrations of mercury than resident lake trout and arctic charr. When comparing only resident fish, I found that lake trout have lower mercury concentrations in lakes with sea-run arctic charr than in lakes without sea-run arctic charr. It will be interesting to see whether this pattern holds true once all of the samples have been analyzed, and if the pattern varies with the contaminant analyzed.

RELEVANCE

Results from my research are intended to be applicable to academia, industry, Northerners, and government. Given the current concern surrounding effects of climate change and industrial development on sea-run arctic charr, I anticipate that many community and industry groups will focus habitat restoration or compensation efforts on the migratory

habitats of this species. Many of these efforts are made in collaboration with government regulators, such as Department of Fisheries and Oceans. For restoration or enhancement plans to be successful, however, we must first understand the ecological consequences of increasing or restoring these fisheries. For instance, will increasing the numbers of sea-run arctic charr lengthen or shorten food chains to lake trout? Will this change have an impact on contaminant concentrations in traditional food fishes? If so, it is possible that this research will help fishers select freshwater fishing sites that are relatively less contaminated. Also, by increasing our knowledge of the natural variability of migration patterns in this species, my research will be useful in evaluating the success of habitat restorations and enhancements for sea-run arctic charr.

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REFERENCES

- CABANA, G., and RASMUSSEN, J.B. 1996. Comparison of aquatic food chains using nitrogen isotopes. *Ecology* 93: 10844–10847.
- DE WIT, C.A., ALAEE, M., and MUIR, D.C. 2006. Levels and trends of brominated flame retardants in the Arctic. *Chemosphere* 64:209–233.
- DINGLASAN, M.J.A., YE, Y., EDWARDS, E.A., and MABURY, S.A. 2004. Fluorotelomer alcohol biodegradation yields poly- and perfluorinated acids. *Environmental Science and Technology* 38:2857–2864.
- ENVIRONMENT CANADA and HEALTH CANADA. 2006. Perfluorinated carboxylic acids (PFCAs) and precursors: A proposed action plan for assessment and management. Ottawa: Environment Canada and Health Canada.

- GIESY, J.P., and KANNAN, K. 2001. Global distribution of perfluorooctane sulfonate in wildlife. *Environmental Science and Technology* 35:1339–1342.
- HIROI, J., and McCORMICK, S.D. 2007. Variation in salinity tolerance, gill Na⁺/K⁺-ATPase, Na⁺/K⁺/2Cl⁻ cotransporter and mitochondria-rich cell distribution in three salmonids *Salvelinus namaycush*, *Salvelinus fontinalis* and *Salmo salar*. *Journal of Experimental Biology* 210:1015–1024.
- JENSEN, J., ADARE, K., and SHEARER, R., eds. 1997. Canadian Arctic Contaminants Assessment Report. Arctic Environmental Strategy. Northern Contaminants Program, Ottawa: Indian Affairs and Northern Development. 460 p.
- JOHNSON, L. 1989. The anadromous arctic charr (*Salvelinus alpinus*) of Nauyuk Lake, N.W.T., Canada. *Physiology and Ecology Japan Special Volume* 1:201–227.
- KIDD, K.A., SCHINDLER, D.W., HESSLEIN, R.H., and MUIR, D.C. 1998. Effects of trophic position and lipid on organochlorine concentrations in fishes from Subarctic lakes in Yukon Territory. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 869–881.
- KLEMETSEN, A., AMUNDSEN, P.A., DEMPSON, J.B., JONSSON, B., JONSSON, N., O'CONNELL, M.F., and MORTENSEN, E. 2003. Atlantic salmon *Salmo salar* L., brown trout *Salmo trutta* L. and arctic charr *Salvelinus alpinus* (L.): A review of aspects of their life histories. *Ecology of Freshwater Fish* 12:1–59.
- MARTIN, N.V., and OLVER, C.H. 1980. The lake charr, *Salvelinus namaycush*. In: Balon, E.K., ed. *Charrs: Salmonid fishes of the Genus Salvelinus*. The Hague: Junk Publishers. 205–277.
- NUNAVUT WILDLIFE MANAGEMENT BOARD. 2004. Final Report: Nunavut Wildlife Harvest Study 1996–2001. Iqaluit: NWMB.
- OOSTDAM, J.V., DONALDSON, S., FEELEY, M., and TREMBLAY, N., eds. 2003. Human health. Ottawa: Indian Affairs and Northern Development.
- POWER, M., DEMPSON, J.B., POWER, G., and REIST, J.D. 2000. Environmental influences on an exploited anadromous arctic charr stock in Labrador. *Journal of Fish Biology* 57: 82–98.
- RIKARDBSEN, A.H., AMUNDSEN, P.A., and BODIN, P.-A. 2003. Growth and diet of anadromous arctic charr after their return to freshwater. *Ecology of Freshwater Fish* 12:74–80.
- SVENNING, M.-A., and GULLESTAD, N. 2002. Adaptations to stochastic environmental variations: The effects of seasonal temperatures on the migratory window of Svalbard arctic charr. *Environmental Biology of Fishes* 64:165–174.
- VAN DE VIJVER, K.I., HOFF, P.T., DAS, K., VAN DONGEN, W., ESMANS, E.L., JAUNIAUX, T., BOUQUEUGNEAU, J.-M., BLUST, R., and DE COEN, W. 2003. Perfluorinated chemicals infiltrate ocean waters: Link between exposure levels and stable isotope ratios in marine mammals. *Environmental Science and Technology* 37:5545–5550.

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