Contaminants and Nutrients in Traditional Food Fishes in Kluane Lake, YT

Science Report

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Summary

The outcomes of a collaborative project led by the Kluane First Nation (KFN), in partnership with the Arctic Institute of Community-Based Research (AICBR), the University of Waterloo, and Western University, are presented here. This research project was initiated by KFN to answer questions about contaminants in fish in Kluane Lake, to determine the health benefits of eating fish from Kluane Lake, and to develop a youth exchange between KFN and university partners. The funded program has accomplished all of the program objectives. The key scientific findings are:

- Average concentrations of mercury in Lake Trout and Lake Whitefish are beneath the Health Canada subsistence consumption guideline for mercury.
- No Lake Trout or Lake Whitefish of any size exceed the Health Canada commercial sale guideline.
- Lake Trout and Lake Whitefish from Kluane Lake **have extremely low concentrations of mercury** compared to other northern Canadian lakes.
- Concentrations of organochlorines in Lake Trout < 750 mm long and average concentrations in Lake Whitefish are beneath US EPA consumption guidelines.
- Lake Trout and Lake Whitefish from Kluane Lake have similar or lower concentrations of organochlorines compared to other northern Canadian lakes.
- Lake Trout and Lake Whitefish in Kluane Lake are rich sources of omega-3 fatty acids and beneficial micronutrients, such as selenium, zinc, and copper.
- Ratios of selenium (nutrient) to mercury (contaminant) in both Lake Trout and Lake Whitefish from Kluane Lake are better than in any other lake in Canada's north.

KFN, AICBR, the University of Waterloo and Western University had a very successful exchange of youth and community members in Spring 2016. KFN youth were involved in many aspects of the research, including fish collection and processing, and mercury analysis. This exchange will hopefully be the first of many that will empower and educate youth as well as contribute to both scientific and traditional knowledge (AICBR related project on traditional knowledge).

Background

The traditional territory of the Kluane Lake People is located in southwestern Yukon Territory along the shores of Kluane Lake. Kluane First Nation is a self-governing First Nation whose citizens live primarily in Burwash Landing and Destruction Bay. Residents depend on traditional subsistence food sources, as the closest grocery store is approximately 300 km away. Traditional foods are often rich sources of nutrients, and contribute to the cultural and spiritual well-being of the community. Citizens of Kluane First Nation have noticed recent changes in the abundance of traditional foods, such as declines in moose populations and the disappearance of Chinook Salmon. The Nation sees other food fish species, such as Lake Trout and Lake Whitefish, as a potential alternative food source, but is worried about levels of contaminants in these fishes; there has been much recent publicity over contaminants (especially mercury) in freshwater food fishes, and Kluane Lake has not received much scientific study.

In partnership with the Arctic Institute of Community-Based Research, the University of Waterloo, and Western University, Kluane First Nation led an initiative to develop a research program that would measure the levels of contaminants of potential concern, along with beneficial nutrients, in Lake Trout and Lake Whitefish harvested from Kluane Lake. This research addresses a component of a larger Community Food Security Strategy that was completed in 2014 (KFN 2014).

Objectives

1. Measure contaminants (mercury, organochlorines, trace metals) in Lake Trout and Lake Whitefish from Kluane Lake.

2. Measure beneficial nutrients (selenium, zinc, omega-3 fatty acids) in Lake Trout and Lake Whitefish from Kluane Lake.

3. Compare results to guidelines and to other northern lakes.

Approach

Fish Collection

During July and August 2015, 245 fish samples were collected from Kluane Lake. Lake Trout samples were collected from July 3 to 5th during the annual Kluane Lake Fishing Derby. Samples were donated by Fishing Derby participants. Small amounts of flesh were taken for chemical analyses and ear bones were collected to determine the fish age. Other measurements were also taken for each fish (length, weight, sex). Lake Whitefish and additional Lake Trout samples were collected during Kluane First Nation's Harvest Camp, which ran from August 24th to 28th, 2015. Fish were collected using gill nets set by Kluane First Nation citizens and youth.

Chemical Analysis

Fish samples were analyzed for mercury and trace metals at Western University, for organochlorines at ALS Environmental, and for fatty acids at University of Waterloo. Standard, internationally accepted methods were used for all analyses. More details are available from H. Swanson upon request (hswanson@uwaterloo.ca).

Results

Organochlorines

Eight Lake Trout and eight Lake Whitefish samples were analyzed for organochlorine concentrations. This analysis costs several hundred dollars per sample, and thus relatively few samples were analyzed. Detected compounds were grouped based on similar chemistry, as shown in Table 1. The term 'organochlorine' as used in this report refers to all of the compounds listed in Table 1.

Table 1. *Organochlorine compounds groups and the names used to describe them in this report.*

Compound	Name Used in Report
Total DDT and related compounds	DDT
Total Lindane and related compounds	Lindane
Total Chlordane and related compounds	Chlordane
Hexachlorobenzene (aka benzene hexachloride)	BHC
Total perchlorinated biphenyls	PCBs

Averages and ranges of fish fork length (size), age, and average contaminant concentrations (and standard deviations) are presented in Table 2. There was much more variation in organochlorine concentrations among Lake Trout than among Lake Whitefish, as indicated by larger standard deviation for Lake Trout data than for Lake Whitefish data. This was expected because there was also much more variation in size and age among Lake Trout than among Lake Whitefish. Lake Trout had higher organochlorine concentrations than Lake Whitefish. This was also expected because Lake Trout grow to be much larger and older than Lake Whitefish.

Table 2. *Average length (range), age (range), and organic contaminant concentrations (SD) of Kluane Lake fish species. 'ND' indicates that the contaminant was not detected. Concentrations are reported in parts per billion (ppb) of contaminant in wet fish flesh samples.*

Species	Fork Length (mm)	Age	DDT (ppb ww)	Lindane (ppb ww)	Chlordane (ppb ww)	BHC (ppb ww)	PCBs (ppb ww)
Lake Trout	713 (492, 968)	19 (9, 31)	12.53 (24.56)	0.33 (0.37)	4.75 (9.26)	1.29 (1.71)	24.52 (48.08)
Lake Whitefish	457 (350, 520)	12 (6, 18)	0.18 (0.49)	0.06 (0.18)	*ND*	*ND*	0.11 (0.32)

Organochlorine concentrations in Lake Trout from Kluane Lake were compared to those found in Lake Trout from Lake Laberge, Kusawa Lake, Atlin Lake, Quiet Lake, and Coal Lake, Yukon. All data are shown in Figure 1. Concentrations of Chlordane and PCBs did not differ significantly among the six Yukon lakes. Lake Trout from Kluane Lake had similar DDT concentrations to those from other Yukon lakes, except for Lake Laberge – Lake Trout from Kluane Lake had significantly lower DDT concentrations than the Lake Trout from Lake Laberge. Lindane concentrations in Lake Trout from Kluane Lake were significantly lower than in Atlin Lake, but did not differ significantly from the remaining lakes. Concentrations of BHC in Kluane Lake Trout did not differ significantly from the other lakes. Average concentrations of most organochlorine contaminants in Lake Trout from Kluane Lake did not exceed US EPA consumption guidelines. Some of the largest Lake Trout captured from Kluane Lake (> 750 mm) had concentrations of PCBs that exceeded consumption guidelines. This size of Lake Trout also had mercury concentrations that exceeded the subsistence mercury consumption guideline (see below). This is not surprising because contaminant concentration increase as fish grow larger and older, and Lake Trout in northern lakes grow to be large and old.

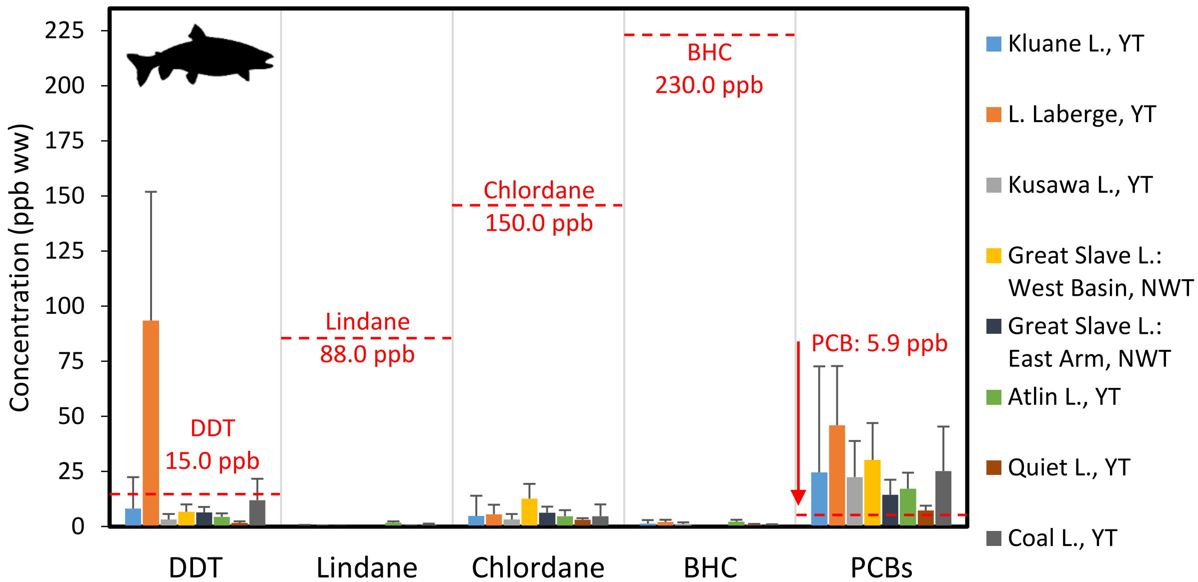

Figure 1. *Average organochlorine concentrations in Lake Trout from (left to right): Kluane Lake, YT; Lake Laberge, YT; Kusawa Lake, YT; Great Slave Lake West Basin, NWT; Great Slave Lake East Arm, NWT; Atlin Lake, YT; Quiet Lake, YT; and Coal Lake, YT. Concentrations are reported in parts per billion (ppb) of contaminant in wet fish flesh samples. Error bars represent 1 standard deviation. Note Lindane and BHC were not analyzed in Great Slave Lake Trout samples. Consumption guidelines for each compound group are shown (red dashed lines). Guidelines from US EPA (2000). Data other than Kluane Lake taken from Fisk et al. (2003) and Stern (2014).*

Organochlorine concentrations in Lake Whitefish from Kluane Lake were compared with concentrations in Lake Whitefish from Watson Lake and Lake Laberge, YT. Data were also compared with Great Slave Lake (West Basin and East Arm), NWT; see Figure 2. Lake Whitefish from Kluane Lake had lower concentrations of DDT and PCBs than Lake Whitefish from Watson Lake, Lake Laberge, and Great Slave Lake. Lindane concentrations did not differ significantly between Kluane Lake and Lake Laberge. Chlordane and BHC were not detected in Lake Whitefish from Kluane Lake.

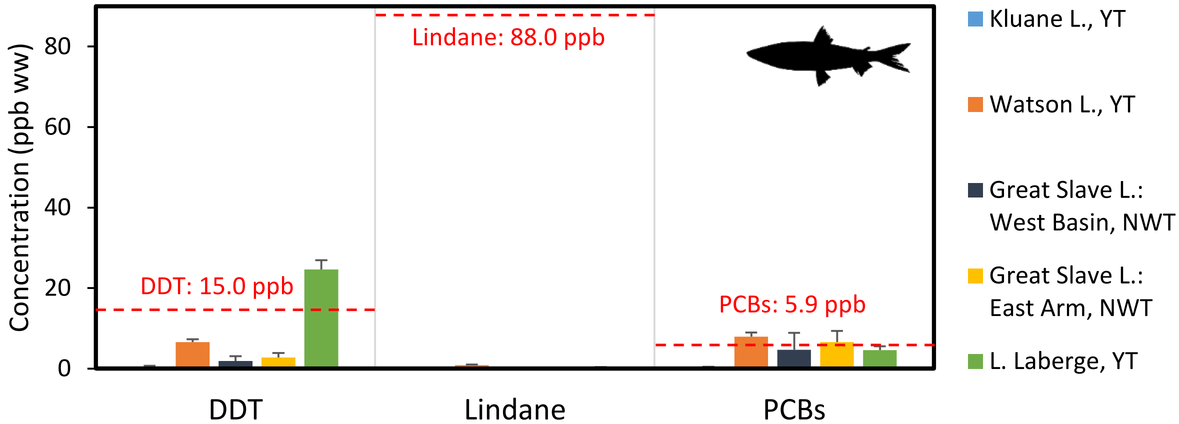

Figure 2. *Average organochlorine concentrations in Lake Whitefish from (left to right): Kluane Lake, YT; Watson Lake, YT; Great Slave Lake West Basin, NWT; Great Slave Lake East Arm, NWT; and Lake Laberge, YT. Concentrations are reported in parts per billion (ppb) of contaminant in wet fish flesh samples. Error bars represent 1 SD. Note Lindane was not analyzed in Great Slave Lake Whitefish samples. Consumption guidelines for each compound group are shown (red dashed lines). Guidelines from US EPA (2000). Data other than Kluane Lake taken from Fisk et al. (2003). Concentrations of DDT, Lindane, and PCBs are so low in Lake Whitefish from Kluane Lake that the results cannot be seen on the graph.*

Subsistence consumption guidelines for organochlorines in fish are presented in Table 3. Consumption guidelines are based on an unrestricted fish-based diet (>16 fish meals/week), and were developed by the US EPA (2000). Lake Trout data were length-standardized to 555 mm fork length in order to represent the organochlorine concentration found in Lake Trout that most people would choose to eat. Due to low organochlorine concentrations and detection in Lake Whitefish, concentrations were not size-standardized.

Length-standardized organochlorine concentrations in Lake Trout from Kluane Lake (at a fork length of 555 mm) were all below the consumption guidelines. Lake Whitefish in Kluane Lake had very low concentrations of organochlorines that were far below the consumption guidelines.

Table 3. *Comparison of size-standardized (555 mm Lake Trout) concentrations of organochlorine contaminants to US EPA guidelines (US EPA 2000). Concentrations are parts per billion of contaminant in wet fish flesh.*

Contaminant	**Concentration Guideline** (ppb ww)	**Kluane Lake Trout** Std. Average (ppb ww)
DDT	15.0	0.86
Lindane	88.0	0.59
Chlordane	150.0	0.69
BHC	230.0	1.35
PCBs	5.9	0.74

Mercury

A total of 98 Lake Trout and 78 Lake Whitefish were analyzed for total mercury concentration in flesh. Average, standard deviation, and range for fish fork length, age, and total mercury concentration are presented in Table 4.

Table 4. *Average (standard deviation in brackets) and range of Fork Length, Age, and Total Mercury Concentration for Lake Trout and Lake Whitefish from Kluane Lake. Concentrations are parts per million mercury in wet fish flesh.*

Species	**Fork Length (mm)**		**Age**		**Total Mercury (ppm)**	
	Average	Range	Average	Range	Average	Range
Kluane Lake Trout	553	257, 968	14 (8)	5, 38	0.078	0.005, 0.390
Kluane Lake Whitefish	403	162, 520	10 (5)	2, 26	0.029	0.009, 0.069

The average concentration of mercury in Lake Trout was higher than in Lake Whitefish. This is expected because Lake Trout grow larger and older than Lake Whitefish, and because Lake Trout feed higher in the food chain. **Both Lake Trout and Lake Whitefish had average mercury concentrations that were beneath the Health Canada Subsistence Mercury Consumption Guideline (0.2 ppm).** Mercury concentrations in Lake Trout and Lake Whitefish increased significantly with both fish age and length; mercury concentrations increase as fish grow longer and get older. Lake Trout smaller than 750 mm fork length (and approx. 20 years old) had mercury concentrations beneath the Subsistence Consumption Guideline. All Lake Whitefish analyzed had mercury concentrations beneath the Subsistence Consumption Guideline.

Lake Trout and Lake Whitefish mercury concentrations were standardized (to 555 mm and 430 mm respectively) in order to compare with an existing database of standardized mercury concentrations in freshwater fishes across northern Canada (Lockhart et al. 2005). Lakes were selected for comparison if the mercury data had been collected since 1990.

Size-standardized Lake Trout mercury concentrations were compared among 42 lakes spanning the Yukon, Northwest Territories, and Nunavut. Lake Trout from Kluane Lake had the lowest mercury concentration of any of these lakes (Figure 3).

Size-standardized Lake Whitefish mercury concentrations were compared among 35 lakes spanning the Yukon and Northwest Territories. Kluane Lake Whitefish had very low mercury concentrations relative to these other lakes (Figure 4).

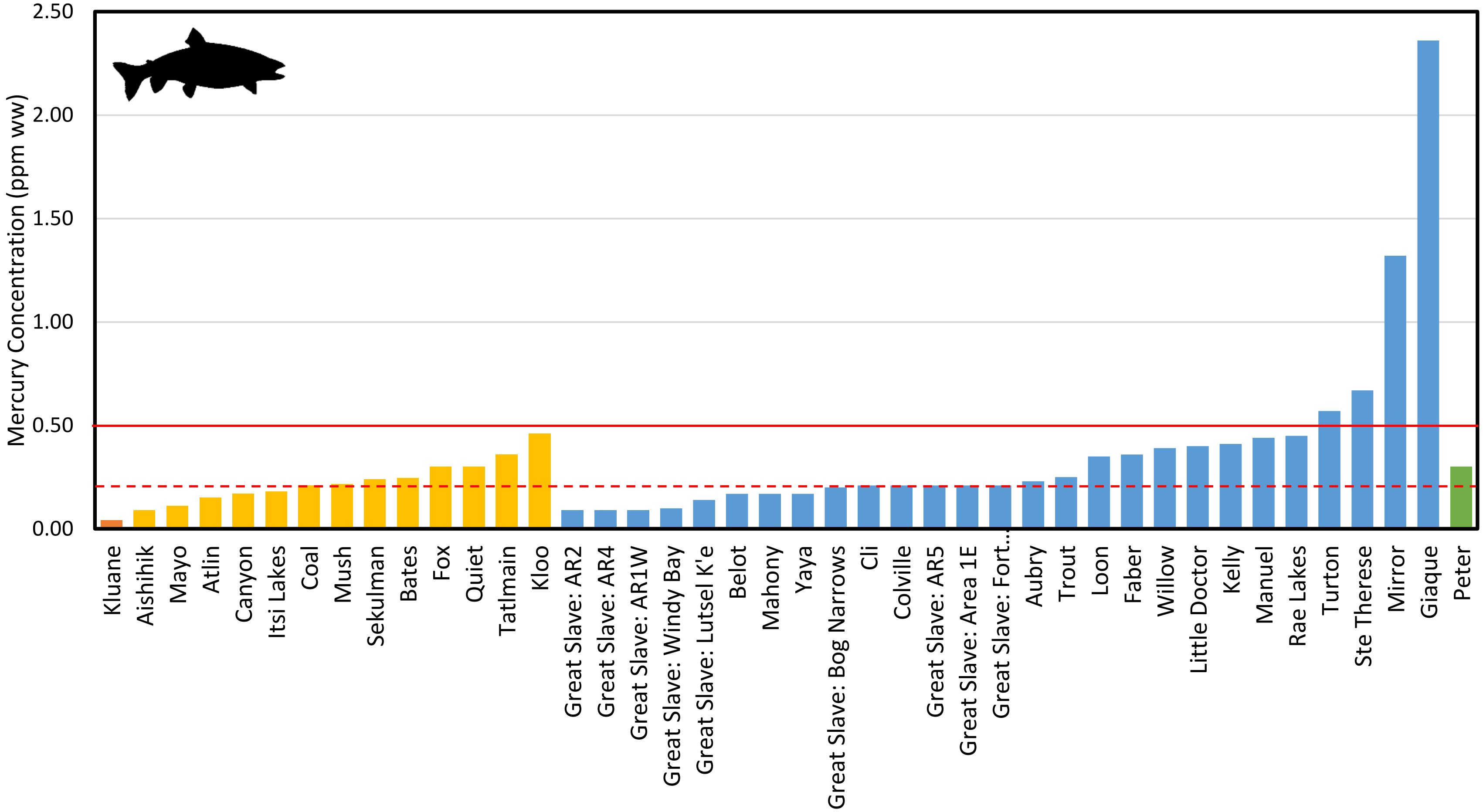

Figure 3. *Size-standardized (at 555 mm fork length) Lake Trout total mercury concentrations in Kluane Lake (orange), select Yukon lakes (yellow), select NWT lakes (blue), and select Nunavut lakes (green). Note: the subsistence consumption guideline for mercury (red dotted line) is 0.2 ppm; the commercial sale guideline for mercury (red solid line) is 0.5 ppm. Data other than Kluane, Mush, and Bates Lakes taken from Lockhart et al. (2005) and Stern (2014). All concentrations are in parts per million mercury in wet fish flesh.*

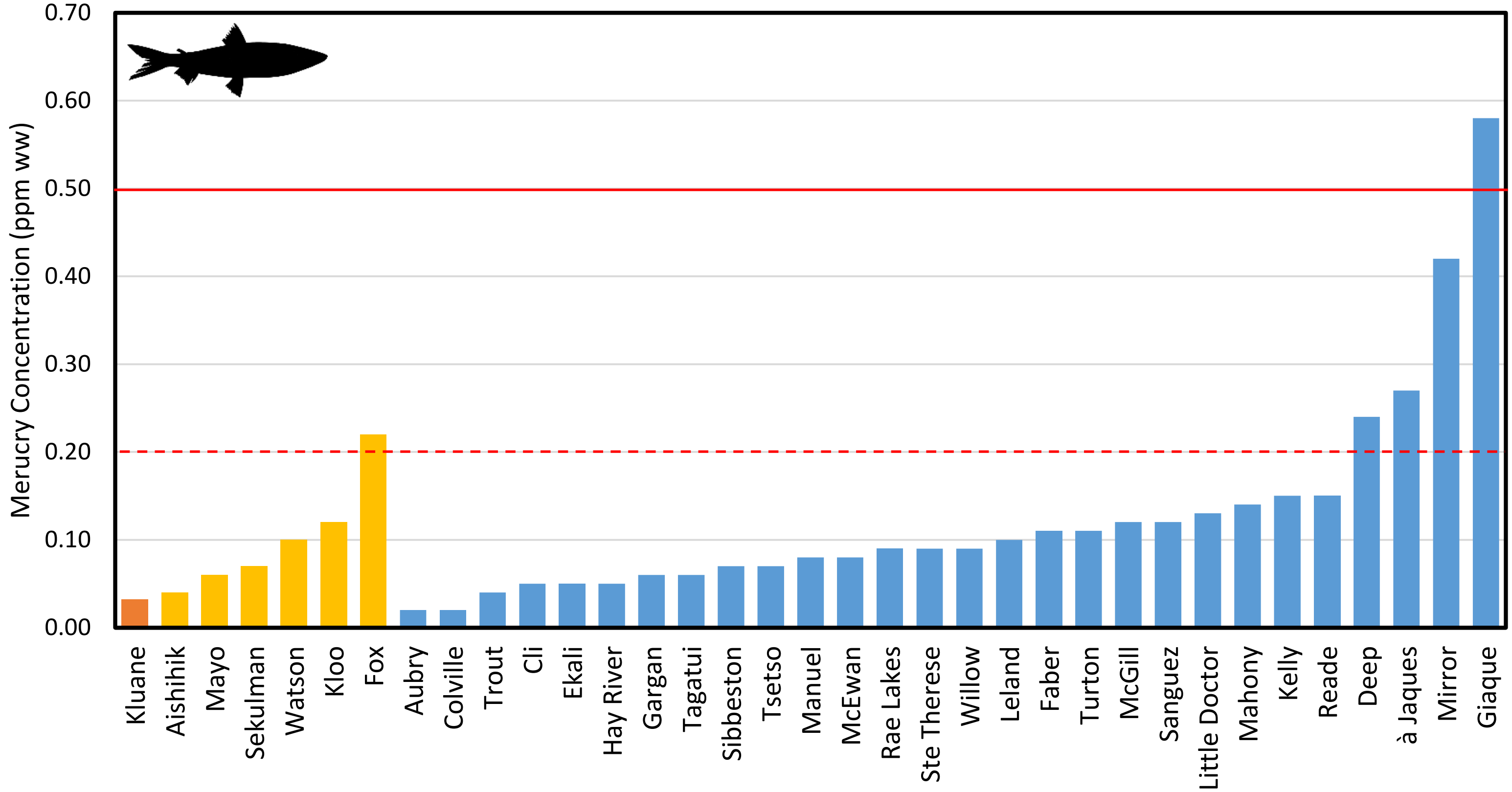

Figure 4. *Size-standardized (at 435 mm fork length) Lake Whitefish total mercury concentrations in Kluane Lake (orange), select Yukon lakes (yellow), and select NWT lakes (blue). Note: the subsistence consumption guideline for mercury (red dotted line) is 0.2 ppm; the commercial sale guideline for mercury (red solid line) is 0.5 ppm. Data other than Kluane, Mush, and Bates Lakes taken from Lockhart et al. (2005). All concentrations are in parts per million mercury in wet fish flesh.*

Trace Metals

A total of 40 Lake Trout and 39 Lake Whitefish were analyzed for trace metals. Some trace metals, such as chromium, cobalt, copper, copper, nickel, selenium, and zinc are essential metals in human diets. They form important components of enzymes and other cellular components. There is some evidence that selenium may protect against effects of mercury exposure. Whether essential or non-essential (non-essential metals include arsenic and cadmium), metals can be harmful in high concentrations. Average concentrations of total arsenic, cadmium, chromium, cobalt, copper, nickel, selenium, and zinc concentrations are presented in Table 5.

Table 5. *Average Trace Metal Concentrations in Kluane Lake fish species. Concentrations are parts per million in wet fish flesh.*

Species	**Arsenic, total** (ppm ww)	**Arsenic, inorganic** (ppm ww)	**Cadmium** (ppm ww)	**Chromium** (ppm ww)	**Cobalt** (ppm ww)	**Copper** (ppm ww)	**Nickel** (ppm ww)	**Selenium** (ppm ww)	**Zinc** (ppm ww)
Lake Trout	0.038	0.004	0.001	0.130	0.010	0.181	0.019	0.790	2.622
Lake Whitefish	0.026	0.003	*nd*	0.143	0.009	0.078	0.029	0.582	4.124

Concentrations of most trace metals did not differ greatly between Lake Trout and Lake Whitefish, except for copper, selenium, and zinc. Lake Trout had higher average copper and average selenium concentrations than Lake Whitefish. Lake Whitefish had higher average zinc concentrations than Lake Trout.

Consumption guidelines have been developed for non-essential metals, such as cadmium and arsenic. In general, only the inorganic form of arsenic is hazardous to human health, whereas the organic form is not hazardous. In fish, approximately 90% of total arsenic is in an organic form and therefore is not hazardous: only 10% is in the hazardous inorganic form. **Based on the total arsenic found in Kluane Lake fish, both Lake Trout and Lake Whitefish are far below the inorganic arsenic consumption guideline of 0.088 ppm (US EPA 2000). Lake Trout cadmium concentration is far below the cadmium consumption guideline of 0.088 ppm (US EPA 2000); cadmium was not detected in Lake Whitefish.** See Table 6 below for average inorganic arsenic and cadmium concentration in Lake Trout, and average inorganic arsenic concentration in Lake Whitefish.

Table 6. *Consumption Guidelines for Select Trace Metals (US EPA 2000). Concentrations are in parts per billion in wet fish flesh.*

Contaminant	**Consumption Guideline** Fish Meals/Month	**Concentration Guideline** (ppb ww)	**Lake Trout** Average (ppb ww)	**Lake Whitefish** Average (ppb ww)
Arsenic (inorganic)	Unrestricted (>16)	88.0	4.79	4.42
Cadmium	Unrestricted (>16)	88.0	6.58	*nd*

Chromium, cobalt, copper, nickel, selenium, and zinc are important micronutrients and are essential in small amounts for human health. Both Lake Trout and Lake Whitefish are excellent sources of these essential micronutrients.

Selenium is an important micronutrient with respect to mercury as there is evidence that this metal may protect against effects of mercury exposure; however, this research is still on-going. The ratio of selenium to mercury is one way to evaluate the relative health benefits and risks of eating fish. A ratio of 1-to-1 selenium-to-mercury (Burger & Gochfeld 2013) was used as a benchmark in this report; ratios above 1 are better.

Average selenium-to-mercury ratios were calculated for Lake Trout and Lake Whitefish from Kluane Lake, and compared with 15 and 10 other northern Canadian lakes, respectively (see Figures 5 and 6). Lake Trout from Kluane Lake had the highest ratio among these lakes, being twice as high as the next highest lake. Kluane Lake Whitefish had a selenium to mercury ratio almost five times greater than the next highest lake. Kluane Lake was the only lake with a selenium to mercury ratio above the benchmark ratio. This means that both Lake Trout and Whitefish from Kluane Lake are likely among the best fish to eat from any lake that has been studied across Canada's northern territories, both because mercury concentrations were so low, but also because selenium concentrations were high.

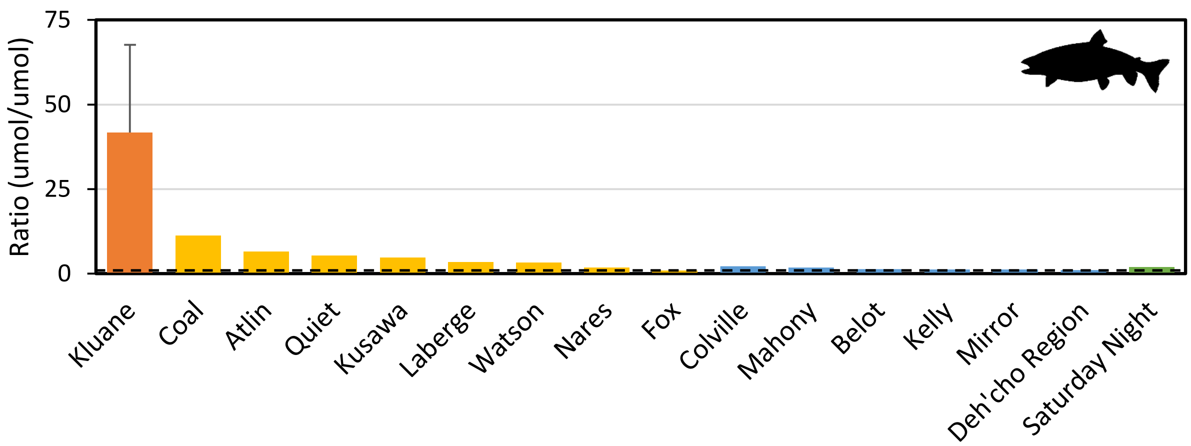

Figure 5. *Selenium-to-mercury ratio for Lake Trout from Kluane Lake (orange), select Yukon lakes (yellow), select NWT lakes (blue), and select Nunavut lakes (green). The benchmark selenium-to-mercury ratio (1:1) is shown (black dashed line). Error bars represent 1 SD. Data other than Kluane Lake taken from Fisk et al. (2003) and Stern (2014).*

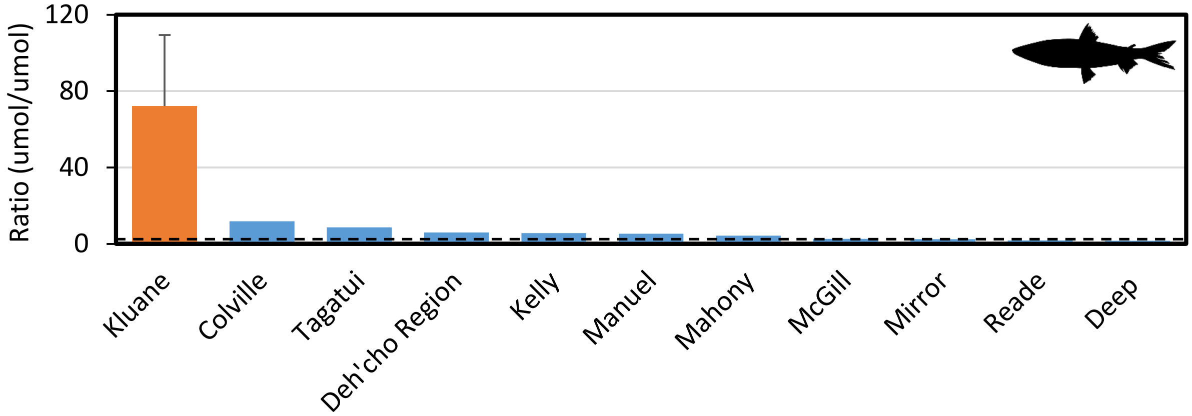

Figure 6. *Selenium-to-mercury ratio for Lake Whitefish in Kluane Lake (orange) and select NWT lakes (blue). The benchmark selenium-to-mercury ratio (1:1) is shown (black dashed line). Error bars represent 1 SD. Data other than Kluane Lake taken from Fisk et al. (2003).*

Fatty Acids

A total of 40 Lake Trout and 24 Lake Whitefish were analyzed for beneficial fatty acids in fish flesh. Fatty acids are complex molecules that are essential components of human cells: omega-3 fatty acids have been shown to act as anti-inflammatory agents and play roles in blood clotting and healthy brain functions (Wall et al. 2010). EPA and DHA are two omega-3 fatty acids that are important for healthy fetal development and heathy ageing. DHA is also important for healthy eye and brain function. Fish and other seafood are excellent sources of these important fatty acids (Swanson et al. 2012). Various studies have shown that consuming higher amounts of these fatty acids can help improve infant health, and help prevent cardiovascular diseases and Alzheimer's disease (Swanson et al. 2012).

Averages and ranges of total omega-3 fatty acid and EPA+DHA concentrations are shown in Table 7.

Table 7. *Average Concentration of Important Fatty Acids in Kluane Lake fish species.*

Species	**Total Omega-3s** (ug/100 g dry)		**EPA+DHA** (ug/100 g dry)	
	Average	Range	Average	Range
Lake Trout	1236.4	101.71 – 12593.9	446.7	15.8 – 2600.9
Lake Whitefish	1052.9	136.21 – 2300.7	567.8	57.2, 1138.6

Average omega-3 and EPA+DHA concentrations did not differ greatly between Lake Trout and Lake Whitefish in Kluane Lake. Both species are rich sources of omega-3 fatty acids, including EPA and DHA.

There is evidence that suggests that omega-3 fatty acids may also protect against mercury exposure. The ratio of DHA-to-mercury can provide risk-benefit information, much like the selenium-to-mercury ratio. A recommended minimum ratio of 17 mg of DHA to 1 µg of mercury was developed by a previous study (Tsuchiya et al. 2008): this ratio allows for individuals consuming fish to get the recommended daily amount of DHA while not surpassing the recommended limit of mercury. DHA-to-mercury ratios were calculated for Lake Trout and Lake Whitefish from Kluane Lake, and compared with the recommended minimum ratio (see Figure 7). Lake Trout and Lake Whitefish from Kluane Lake had DHA-to-mercury ratios significantly above the recommended minimum ratio.

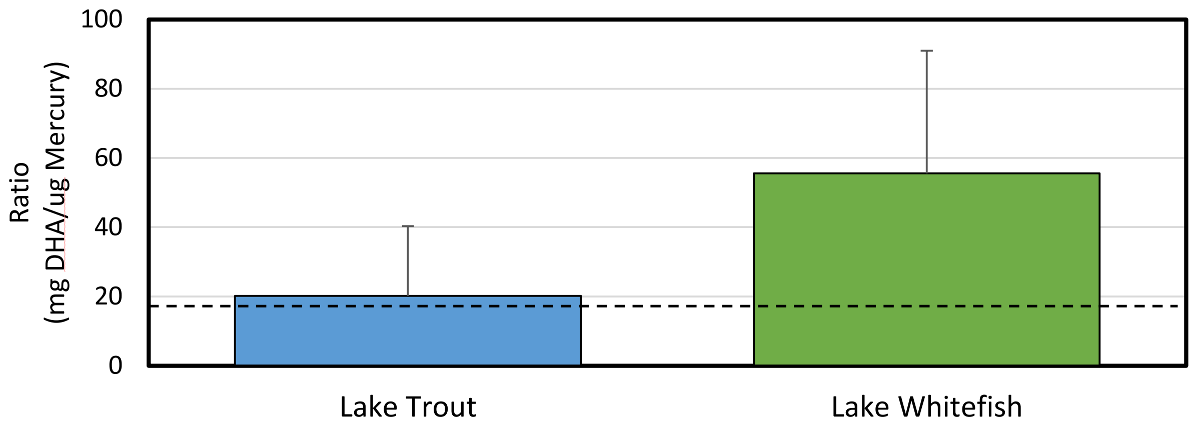

Figure 7. *DHA to mercury ratio (mg DHA/ug Hg dw) for Lake Trout and Lake Whitefish in Kluane Lake. The recommended minimum DHA-to-mercury ratio (17:1) is shown (black dashed line).*

Risks & Benefits of Kluane Lake Fish

Overall, Lake Trout and Lake Whitefish from Kluane Lake had low average concentrations of environmental contaminants and high concentrations of beneficial nutrients, such as omega-3 fatty acids and selenium. Since Lake Trout live a long time and grow to be over 1 meter long, they can accumulate more contaminants than younger, smaller Lake Trout. Mercury and PCBs were found to approach or exceed consumption guidelines in very large, very old Lake Trout from Kluane Lake. It is recommended that people choose Lake Trout that are less than 750 mm long to eat (see Figure 8). Lake Whitefish of any size are good to eat.

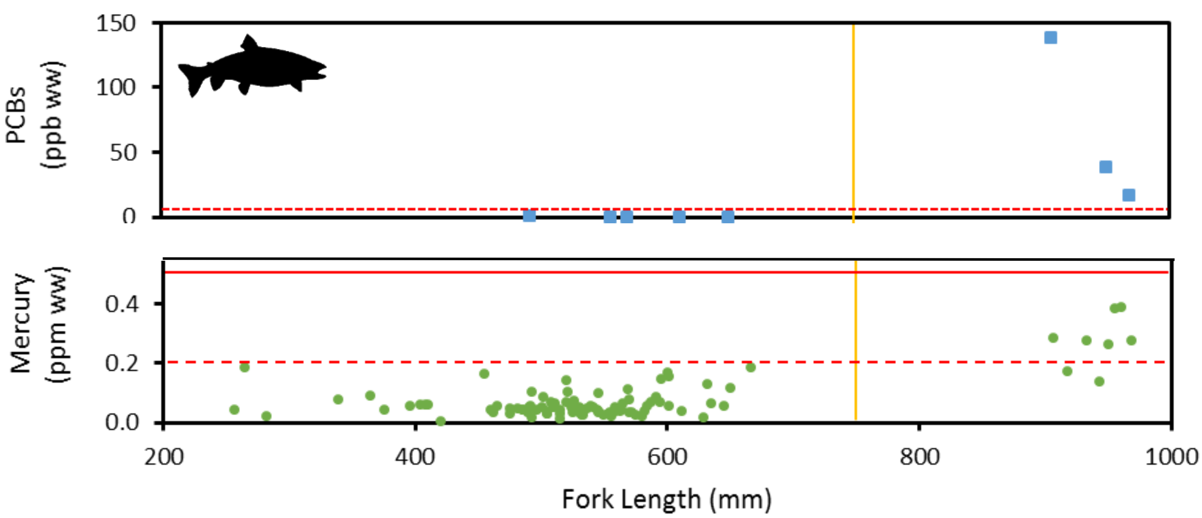

Figure 8. *PCBs (top) and mercury (bottom) concentrations in Lake Trout from Kluane Lake with respect to fork length (size). US EPA consumption guideline for PCBs shown with a red dashed line (top); Subsistence Consumption and Commercial Sale Guidelines for Mercury shown with a red dashed line and a red solid line, respectively (bottom). The recommended maximum eating size for Lake Trout is 750 mm fork length, shown with a yellow solid line.*

Through this collaborative research project, we have determined that Lake Trout and Lake Whitefish from Kluane Lake are healthy traditional food sources.

Kluane First Nation – University Scientific Exchange

In late March 2016, two Kluane First Nation youth, a youth councillor, Norma Kassi from AICBR, and an Indigenous filmmaker travelled to southern Ontario to learn about the tasks in the laboratory that need to be done to measure mercury in Kluane fish. Over two days, the group learned about the preparation required to sample a fish and get the flesh ready for analyses at the University of Waterloo, and then travelled to Western University to actually conduct the analyses on Kluane fish. The data generated are part of the dataset presented here. On both days the group was received with a traditional greeting from each University's Indigenous Services and gained experience on the two university campuses. The visit resulted in good media attention, and a high level of interest from the Universities. The University research teams look forward to future scientific exchanges with Kluane First Nation.

Continuing Work

A peer-reviewed publication will follow this report, and will be published in the next 18 months.

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