Associations Between Omega-3 fatty Acids, Selenium Content, and Mercury Levels in Wild-harvested Fish from the Dehcho Region, Northwest Territories, Canada

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INTRODUCTION AND RESEARCH OBJECTIVES

Fish provide a rich variety of important nutrients [e.g. omega-3 fatty acids (*n*-3 FAs) and selenium (Se)]. The intake of *n*-3 FAs from fish consumption promotes healthy growth and development in infants and children (SanGiovanni & Chew, 2005), supports optimal cognitive health in older adults (Dangour & Uauy, 2008), and reduces the risk of cardiovascular disease (Calder, 2004). The intake of the essential trace element, Se, is important to maintain thyroid hormone metabolism (Arthur, 1991), potentially protect against cardiovascular disease (Rayman, 2012), and may reduce the incidence of some cancer types (Vinceti et al., 2014). However, methylmercury (MeHg), a contaminant commonly detected in fish, is known to induce adverse health effects in neurological, cardiovascular, immune, and endocrine systems.

Several lakes in the Dehcho Region contain fish populations with elevated total mercury (HgT) concentrations (Lockhart et al., 2005). For example, in some inland lakes, the mean Hg concentration of predatory fishes like Walleye, Northern Pike, and Lake Trout approached or exceeded the 0.5 ppm Health Canada HgT guideline. Situations among subsistence populations, including Dehcho residents of who have limited alternatives to fish sources, may face the dilemma of weighing the risks and benefits. Focusing solely on the risks of Hg, however, can overlook the nutritional benefits provided by fish consumption.

To promote traditional food use as a pathway to health equity, the following research objectives have been developed:

1. To quantify the levels of total Hg, *n*-3 FAs, and Se in fish species harvested from three lakes in the Dehcho Region, Northwest Territories (NWT)
2. To evaluate the correlations between nutrient and contaminant concentrations and identify which fish species provide the most *n*-3 FA and Se relative to their Hg content

RESEARCH METHODOLOGY

Data Collection

- Seven species of freshwater fish included: Burbot (*Lota lota*), Cisco (*Coregonus artedi*), Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*), Longnose Sucker (*Catostomus catostomus*), Northern Pike (*Esox Lucius*), and Walleye samples (*Sander vitreus*)
- Sample collection time frame: August 2013
- The samples were collected from Ekali, Sanguez, and Trout Lakes in the NWT

Laboratory Analysis

- **Mercury Analysis.** Fish tissue samples were freeze dried without skin and ground prior to analysis. Analysis for Hg was measured via a direct mercury analyzer (Milestone DMA-80).
- **Selenium Analysis.** 100 mg of pulverized fish muscle tissue was digested with 5 mL of HNO_3 and 1.5 mL of H_2O_2. Samples were re-diluted with 3.5 or 5 mL of 2% HNO_3 and filtered. Analysis for Se was measured by an inductively coupled plasma mass spectrophotometer (Thermo X Series II).

- **Omega-3 Fatty Acids Analysis.** 100 mg of pulverized fish muscle tissue was homogenized with 2 mL $CHCl_3$: 1 mL MeOH containing 22:3*n*-3 ethyl ester as the internal standard. 50 µg/mL of butylated hydroxytoluene was also included in the extraction reagents to prevent oxidation. The sample was centrifuged and the organic extract was evaporated under N_2 gas by 300 µL of hexane. Analysis for the lipid extracts was measured by a gas chromatograph with a flame ionization detector (Varian 3900).

RESULTS AND DISCUSSION

Table 1. Total Mercury and Selenium Concentrations by Fish Species

Fish Species	Mercury			Selenium		
	n	Range (ppm)	Mean ± S.D. (ppm)	n	Range (ppm)	Mean ± S.D. (ppm)
Burbot	9	0.228 - 0.551	0.317 ± 0.101	6	0.117 - 0.155	0.141 ± 0.013
Cisco	29	0.020 - 0.194	0.057 ± 0.045	10	0.116 - 0.239	0.174 ± 0.042
Lake Trout	13	0.207 - 0.643	0.330 ± 0.153	11	0.078 - 0.140	0.140 ± 0.056
Lake Whitefish	29	0.025 - 0.150	0.073 ± 0.038	15	0.086 - 0.307	0.173 ± 0.069
Longnose Sucker	6	0.086 - 0.127	0.100 ± 0.015	5	0.170 - 0.215	0.187 ± 0.020
Northern Pike	48	0.070 - 3.121	0.551 ± 0.598	28	0.090 - 0.229	0.140 ± 0.032
Walleye	53	0.036 - 1.428	0.415 ± 0.305	22	0.089 - 0.284	0.195 ± 0.039

Table 2. Fatty Acid Composition by Fish Species

Fish Species	n	Total Omega-3 Fatty Acids		EPA+DHA		Omega-6 to Omega-3 Ratios	
		Range (mg/100g)	Mean ± SD (mg/100g)	Range (mg/100g)	Mean ± SD (mg/100g)	Range	Mean ± SD
Burbot	9	68.4 – 127	101 ± 18.2	57.4 – 110	86.3 ± 16.3	`0.45 - 0.60	0.49 ± 0.04
Cisco	12	187 – 551	346 ± 115	145 – 344	224 ± 58.9	0.24 - 0.41	0.30 ± 0.06
Lake Trout	11	258 – 4,375	1,689 ± 1,294	172 – 2,332	965 ± 544	0.28 - 0.62	0.41 ± 0.15
Lake Whitefish	24	215 – 2110	458 ± 401	182 – 1,048	299 ± 187	0.22 - 0.53	0.38 ± 0.09
Longnose Sucker	6	208 – 763	499 ± 198	160 – 372	263 ± 68.6	0.45 - 0.69	0.54 ± 0.10
Northern Pike	37	131 – 836	212 ± 123	113 – 707	176 ± 98.6	0.20 - 0.48	0.34 ± 0.06
Walleye	35	117 – 911	230 ± 148	87.5 – 807	198 ± 131	0.21 - 0.47	0.34 ± 0.06

Mercury Concentrations

- Predatory fish [including Northern Pike (0.551 ppm), Walleye (0.415 ppm), and Lake Trout (0.330 ppm)] had higher Hg concentrations than observed in benthivorous and planktivorous fish species [e.g. as Cisco (0.057 ppm) and Lake Whitefish (0.073 ppm)]
- Hg content increased with fork length and/or weight for most of the test fish species (P <0.001)
- According to ANOVA, Hg concentrations differed between lakes for most of the studied species. The highest HgT levels (P <0.05) were observed in Sanguez Lake for Cisco, Lake Whitefish, Northern Pike, and Walleye

Selenium Concentrations

- In contrast to the Hg results, average Se concentrations were quite similar between species, ranging from 0.140 to 0.195 ppm for Northern Pike and Walleye, respectively
- Generally, Se concentrations were not correlated with either fork length or weight
- As seen with Hg, Se concentrations within fish species differed between lakes. However, the highest Se contents (P <0.05) for Cisco, Lake Whitefish, Northern Pike, and Walleye were observed in Trout Lake

Fatty Acid Composition

- There were substantial differences in fatty acid profiles between fish species:
  - Lake Whitefish, the most commonly consumed fish in the Dehcho Region, had *n*-3 FA levels (458 mg/100 g) that were 2.1-fold higher than in some predatory fish species, such as Northern Pike (212 mg/100g) and Walleye (230 mg/100g)
  - The EPA+DHA concentrations in Lake Trout (965 mg/100g) were up to 11.2-fold higher than Burbot (86.3 mg/100g), Northern Pike (176 mg/100g), and Walleye (198 mg/100g)
  - All of the fish species analyzed had greater levels of health promoting *n*-3 FA relative to their pro-inflammatory *n*-6 FA content
- Typically, *n*-3 FA content was not correlated with fork length and weight; the lone exception was Lake Whitefish (P <0.01)
- The highest *n*-3 FA levels (P <0.05) were observed in Ekali Lake for Walleye, Sanguez Lake for Lake Whitefish, and Trout Lake for Northern Pike

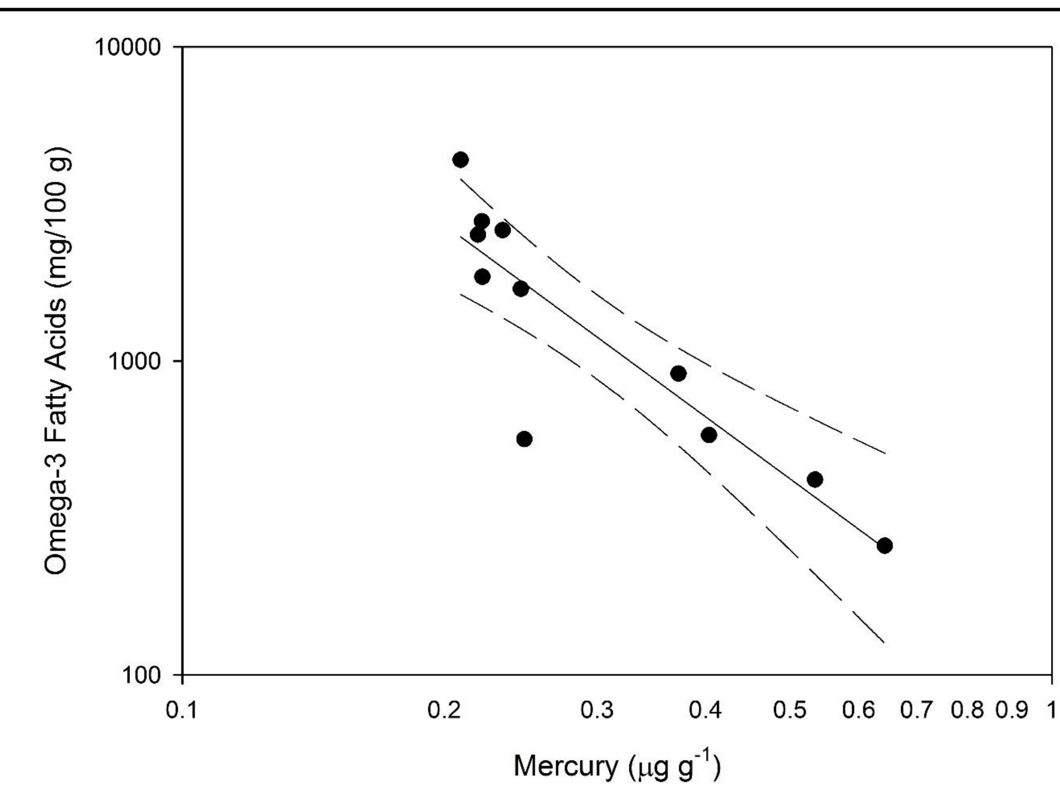

Figure 1. Relationship between total mercury concentration and omega-3 fatty acid content in Lake Trout

- Strong negative correlations were observed between HgT and *n*-3 FA content for Lake Trout (ρ = -0.937, P <0.001), Northern Pike (ρ = -0.619, P <0.001), and Walleye (ρ = -0.481, P <0.01)
- There were also significant negative correlations between Hg and Se observed for Lake Whitefish (ρ = -0.818, P <0.001), Cisco (ρ = -0.685, P <0.05), and Northern Pike (ρ = -0.410, P <0.05)
- To the knowledge of the authors, this represents the first time that researchers have demonstrated strong, negative correlations between Hg and nutrient content in particular fish
- From a risk-benefit perspective, the presence of negative correlations can contribute to substantial intra-species variation in nutrient:Hg ratios

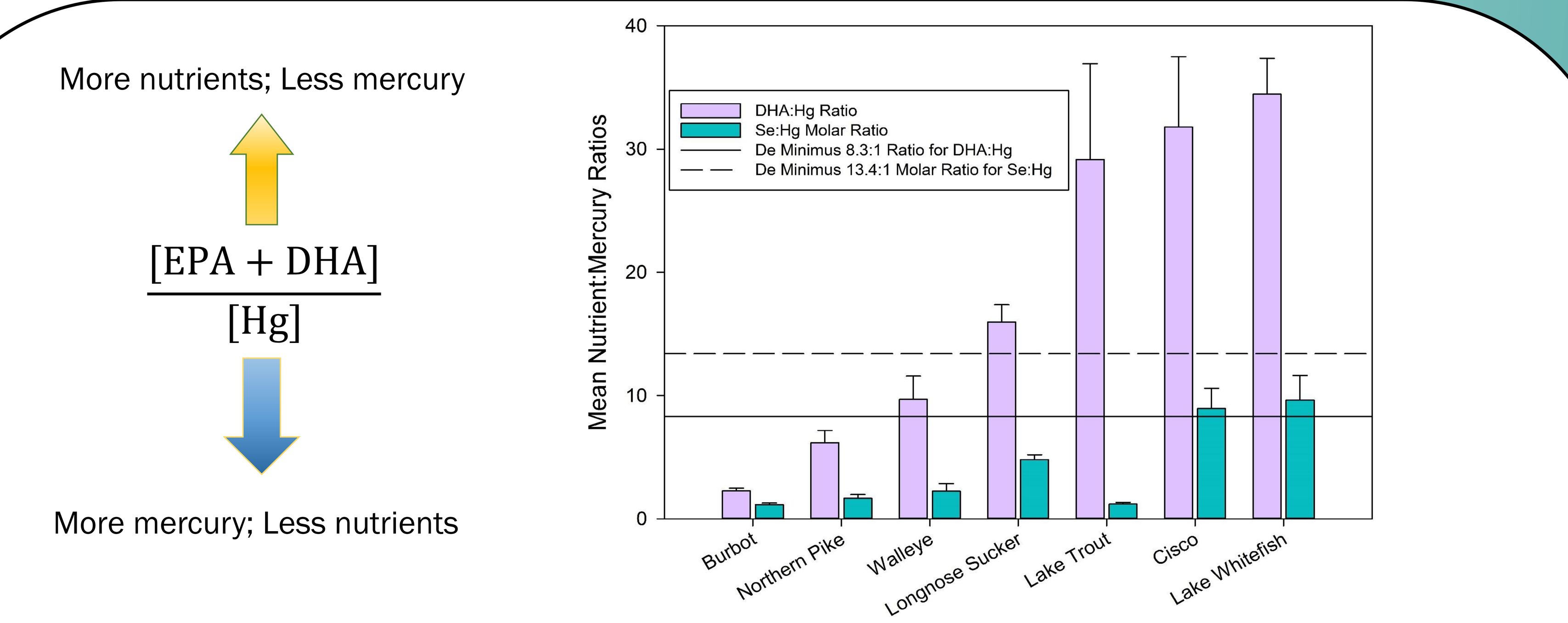

Figure 2. Comparison of nutrient: mercury ratios to the *de minimus* ratios from Health Canada's mercury regulatory guidelines

- A method proposed by Tsuchiya et al. (2008) defined a *de minimus* intake ratio of 17 mg DHA to 1 µg of Hg exposure, such that individuals consuming fish over this *de minimus* ratio would be able to meet the Dietary Reference Intake of DHA (100 mg/day) while not exceeding the U.S. EPA reference dose (RfD) for MeHg (0.1 µg/kg/day)
- To make the *de minimus* approach more relevant to the Canadian regulatory context, we applied Tsuichya et al. (2008) method using Health Canada's Hg toxicological reference value (TRV) for pregnant women and women of child-bearing age (Legrand et al. 2010)
- Of the seven freshwater fish species collected in this study, Walleye, Longnose Suckers, Lake Trout, Cisco, and Lake Whitefish, on average, exceeded the *de minimus* ratio for DHA:Hg (8.3:1)
- In contrast, all seven of the species were below the *de minimus* molar ratio for Se:Hg (13.4:1). However, it is not yet known how high the Se:Hg molar ratio has to be to protect against MeHg's adverse effects

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