Whole fish vs. fish fillet—The risk implications for First Nation subsistence consumers

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Abstract: Consumption advisories associated with mercury concentrations are typically based on consumption of fish fillets; however, many First Nation community members consume more than just the fish fillet because of both preference and availability. Food frequency questionnaires were completed by 106 community members to identify which parts of the fish were typically and preferentially consumed. The results of the questionnaires showed that, depending on the species of fish, between 20% and 100% of the respondents ate more than just the fish fillet. Two northern Alberta First Nations harvested 73 piscivorous fish as part of separate studies investigating fish quality. Fillets and whole fish from two species, northern pike (Esox lucius) and walleye (also known as pickerel; Sander vitreus), were analyzed for mercury concentrations. Measured mercury concentrations in whole fish were significantly lower than in fillets ($p < 0.05$ in all cases). This paper investigates the implications of fish consumption advisories for First Nation communities where many subsistence consumers eat more than just the fish fillet. Consideration of traditional consumption practices may result in a more accurate assessment of exposure for the development of fish consumption guidelines.

ABOUT THE AUTHORS

Intrinsik Corp. has significant expertise in the completion of Traditional (or Country) Food Studies. Traditional foods are those foods harvested from either the land or water, and include plants, birds, fish, sea mammals and other large and small game animals. Our scientists, led by Claire McAuley, have completed numerous studies alongside First Nations across Canada. Both Swan River First Nation (SRFN) and Chipewyan Prairie Déné First Nation (CPDFN) have completed investigations of their traditional food quality. As part of these studies, Intrinsik (working with SRFN and CPDFN) evaluated risks from ingestion of harvested subsistence foods and provided assurances as to the quality and safety of locally sourced foods. The Traditional Food Studies involved the submission of food samples by trained community harvesters, the analysis of trace contaminants in these samples and, in order to evaluate health risk, the integration of community consumption rates obtained through surveys and interviews.

PUBLIC INTEREST STATEMENT

Consumption of traditional foods is very important for First Nations members. Fish are a critical element of the diet for many First Nations members but are also the greatest potential source of mercury in the diet. When consumed, methyl mercury from fish muscle can accumulate in the body over time and can act as a neurotoxicant. Fish consumption guidelines protective of the general public, based on the fillet mercury concentration alone, may be over-protective for First Nations for whom consumption of all components of a harvested animal is important. Mercury concentrations were measured in whole fish and fish fillets in two species of commonly consumed fish. The mercury concentrations in the whole fish were significantly lower than in fillets alone. Subsistence fishers need to be aware of the presence of mercury in fish tissues; however, advisories based on the fillet concentration alone may not be appropriate for all consumers.
1. Introduction

With many First Nation members continuing to enjoy a diet consisting mainly of traditional foods, fish remains a critical element of the diet and the reinforcement of fish quality is important with respect to food security. Fish has a high protein value and is both a primary source of omega-3 long chain polyunsaturated fatty acids (Health Canada, 2007a) and a recommended component of a balanced diet (Health Canada, 2007b). Fish is also the greatest potential source of mercury in the diet, therefore subsistence fishers need to be aware of the presence of naturally occurring mercury in fish tissues and the potential consumption limitations.

Mercury is the principal metal of concern in fish (Canadian Council of Ministers of the Environment (CCME (Canadian Council of Ministers of the Environment), 2000); Health Canada, 2016). Humans are exposed to low levels of mercury directly from air and water; however, eating piscivorous fish is the most common pathway to introduce methyl mercury to the human body (WHO, 2008). Fish consumers may be exposed to relatively higher levels of methyl mercury by eating mercury-containing fish. Methyl mercury can accumulate in the human body over time, can cross both the blood-brain barrier and the placental barrier and can act as a neurotoxicant. Since methyl mercury is a known neurotoxin, it is necessary to limit human exposure; therefore, there are mercury-related guidelines for the consumption of fish in order to protect the general public. Health Canada has guidelines for daily mercury intake for the general adult population, women of childbearing age and children under the age of 18 (Health Canada, 2010). The guidelines are most stringent for children and women of childbearing age and are intended to be protective of human health. Summary documents identifying the mercury concentrations in both commercially available fish, both fresh and canned, and in sport fish have been published by Health Canada and Alberta Health, respectively. The balance of health benefit and exposure risk for fish consumers has been identified (Alberta Health 2016; Health Canada, 2007b).

Fish consumption advisories are typically based on methyl mercury concentrations in fish fillets; however, consumption of all components of a harvested animal is important to First Nations and exposure to methyl mercury when consuming more than just the fillet may result in a lower average exposure concentration. The activities of harvesting, processing, and consuming fish are vital to the development and maintenance of the Nation’s culture and identity, and are important in the transfer of knowledge between generations (Furgal, Powell, & Myers, 2005; Condon, Collings, & Wenzel, 1995; Kuhnlein & Soueida, 1992; Natcher, 2008; Nuttall et al., 2005; Van Oostdam et al., 2005; Wien & Freeman, 1992). The communication of clearer information in consumption advisories is important in balancing and recognizing both the potential health impacts of methyl mercury and the importance of fish as a traditional and subsistence food source for many First Nations. Food security issues in northern Alberta are far more severe among First Nations’ households than the non-Indigenous population (Chan et al., 2016). Beyond the economic and dietary benefits of consuming traditional food like fish, it also plays a critical social and cultural role in First Nations communities. As such, it important to ensure that food advisories are as accurate as possible because over-protection may lead to moderate or extreme food insecurity among First Nations’ households and the negative implications that accompany those conditions. The objective of this study was to identify whether the methodology for current fish advisories based on mercury exposure may “over-protect” consumers who eat more than the fish fillet.

The two First Nations who participated in the study, Swan River First Nation (SRFN) and the Chipewyan Prairie Déné First Nation (CPDFN), live in proximity to Lesser Slave Lake and Hook, Kirby and Winefred Lakes respectively. Lesser Slave Lake is adjacent to conventional oil and gas,
agriculture, and forestry while Hook, Winefred, and Kirby Lakes are in the southern oil sands area of Alberta, south of Fort McMurray, and are adjacent to extensive and intensive in-situ oil sands development. The fish species evaluated in the study are jackfish (northern pike) (*Esox lucius*) and pickerel (walleye) (*Sander vitreus*). These species were chosen as they are two of the three most commonly consumed (other species being whitefish [*Coregonus clupeaformis*]) and are the species of most concern as related to mercury.

2. Methods
To address community concerns from SRFN and the CPDFN, regarding the proximity and encroachment of industrial developments and their impact on traditional food quality, two studies were conducted to evaluate fish quality. These studies involved Elders, youth and other community members in the study planning and implementation, in the collection of fish and in the transfer of traditional knowledge. Surveys were conducted with members of the two communities about their fish-eating habits and contained questions about the species of fish consumed, amount consumed per season, parts of the fish eaten and the typical portion sizes. Only adults were included in the survey. The survey was approved by the Health Canada Research Ethics Board.

Community fishers harvested jackfish, pickerel and whitefish. In total, 84 fish were collected from Hook, Kirby and Winefred Lakes by members of the CPDFN. Fish were collected by angling at Hook Lake on 9 September 2016 (9 jackfish and 3 pickerel), by netting at Kirby Lake on 15 September 2016 (10 jackfish), and again by netting at Winefred Lake on 19 January 2017 (17 jackfish and 9 pickerel). Additionally, 36 whitefish were harvested; however, as whitefish are benthopelagic fish and do not bioaccumulate mercury, they were not included in this study. Twenty-five fish were collected from Lesser Slave Lake by members of the SRFN in early 2017, including 18 pickerel and seven jackfish. Lakes included in the study are shown in Figure 1.

All of the fish harvested were identified to be in good condition with no abnormalities. All fish were weighed and were measured to determine their fork length (Table 1). All samples

![Figure 1. Map showing lakes.](https://example.com/map.png)
were kept frozen until they were received by Maxxam Analytics in Edmonton, Alberta. Fish samples were homogenized in their entirety (fillets or whole fish) prior to undergoing analysis. Mercury in fish tissues were analyzed using cold vapor atomic fluorescence spectroscopy (CVAFS) and were reported as a component of the suite of metals by Maxxam Analytics in Edmonton, Alberta.

3. Results
A single factor analysis of variance was conducted for mercury concentrations in fillets of both fish species across all of the lakes in order to test whether samples from all lakes could be grouped as a single population for further analysis. Mercury concentrations between lakes, unadjusted or normalized to either fish weight or fork length, were significantly different for both pickerel ($p < 0.05$) and jackfish fillets ($p < 0.01$). As a result, it was not appropriate to pool samples from different lakes for each species. The weight and fork length for each of the two species were plotted (regardless of location) and a “clear” association was identified between weight and length (Figure 2). Based on this information, it can be seen that the sample dataset included fish of a wide range of sizes and weights which might typically be consumed, and these data fit the typical trend expected for fork length and weight.

3.1. Exposure point concentration of mercury in each fish species
Summary statistics were calculated for both whole and fillet samples for each species from each of the lakes (Table 2). While the summary statistics provide details as to the fish populations in each of the lakes, the difference in mercury concentrations between the whole fish and the fillet samples is shown clearly in the box and whisker plots (Figure 3).

The analytical results for the mercury concentrations of each of the fillets and whole fish for the jackfish and pickerel samples were further compared to determine if the

| Table 1. Fish samples and fork length |
|--------------------------------------|
|                                       |
| Fish species | Fillets | Whole fish | Fillets | Whole fish |
|------------------|----------|-------------|----------|-------------|
| Pickerel (walleye) | 25        | 5           | 30.5–63  | 33.0–56.5  |
| Jackfish (pike)   | 33        | 10          | 48.3–99  | 48.3–85    |

Figure 2. Fork length vs weight for jackfish and walleye.
### Table 2. Summary statistics for mercury in fish samples

| Location       | Fish species | Fillet or WHOLE | Sample size | Min | Max | Mean | 95 UCLM | 90th percentile | 95th percentile |
|----------------|--------------|-----------------|-------------|-----|-----|------|---------|----------------|----------------|
| Hook Lake      | Jackfish     | Fillet          | 6           | 0.16| 0.45| 0.33 | 0.41    | 0.42            | 0.43            |
|                |              | Whole           | 3           | 0.01| 0.09| 0.05 | NC      | NC             | NC             |
|                | Pickerel     | Fillet          | 3           | 0.11| 0.33| 0.22 | NC      | NC             | NC             |
| Kirby Lake     | Jackfish     | Fillet          | 7           | 0.12| 0.26| 0.19 | 0.23    | 0.25            | 0.26            |
|                |              | Whole           | 3           | 0.05| 0.14| 0.11 | NC      | NC             | NC             |
|                | Pickerel     | Fillet          | 7           | 0.08| 0.32| 0.16 | 0.22    | 0.26            | 0.29            |
|                |              | Whole           | 2           | 0.13| 0.15| 0.14 | NC      | NC             | NC             |
| Winefred Lake  | Jackfish     | Fillet          | 14          | 0.07| 0.31| 0.17 | 0.20    | 0.26            | 0.29            |
|                |              | Whole           | 3           | 0.03| 0.07| 0.06 | NC      | NC             | NC             |
|                | Pickerel     | Fillet          | 7           | 0.08| 0.32| 0.16 | 0.22    | 0.26            | 0.29            |
|                |              | Whole           | 2           | 0.13| 0.15| 0.14 | NC      | NC             | NC             |
| Lesser Slave Lake | Jackfish  | Fillet          | 6           | 0.20| 0.52| 0.33 | 0.42    | 0.45            | 0.48            |
|                |              | Whole           | 1           | 0.19| 0.19| 0.19 | NC      | NC             | NC             |
|                | Pickerel     | Fillet          | 15          | 0.13| 0.75| 0.36 | 0.44    | 0.57            | 0.65            |
|                |              | Whole           | 3           | 0.08| 0.16| 0.12 | NC      | NC             | NC             |

NC = not calculated due to low sample size.
concentrations were statistically different from one another when examined at a lake level. For this comparison, the Student’s t-test was used, assuming unequal variance and a two-tailed distribution at a significance level of 0.05. The results of the t-test indicate that mercury concentrations are significantly different between whole fish and fillets in jackfish in Hook and Winefed Lakes and pickerel in Lesser Slave Lake. Sample sizes of whole fish for pickerel in Winefred Lake and jackfish in Lesser Slave Lake were <3; therefore, the t-test was not completed for these populations (Table 3). The mercury concentrations in jackfish from Kirby Lake were considered statistically similar; however, the p-value only marginally exceeded 0.05 (p = 0.058).

Table 3. Student’s t-test results summary, pickerel whole fish vs. fillet

| Mean mercury concentration (mg/kg) | Interpretation          |
|-----------------------------------|-------------------------|
|                                   | Fillet Hg | Whole fish | p-value |
| **Jackfish**                      |           |            |         |
| Hook Lake                         | 0.33      | 0.05       | 0.0005  | Reject null hypothesis; population means unequal |
| Kirby Lake                        | 0.19      | 0.11       | 0.058   | Accept null hypothesis; population means equal |
| Winefred Lake                     | 0.17      | 0.06       | 0.0018  | Reject null hypothesis; population means unequal |
| **Pickerel**                      |           |            |         |
| Lesser Slave Lake                 | 0.36      | 0.12       | 0.0003  | Reject null hypothesis; population means unequal |
3.2. Consumption preference results
Those participants responding to the consumption survey were individuals who self-identified as “fish eaters”. Surveys were administered in two communities resulting in 106 respondents indicating that they consumed fish on a regular basis. All available fish species harvested by the communities were included in the survey. Fish identified as being consumed by survey respondents included jackfish, pickerel, whitefish, mariah ((burbot) *Lota lota*) and white sucker (*Catostomus commersonii*). Overall, pickerel and whitefish were the most commonly consumed fish. A significant proportion of the population consumed more than just the fish fillets (Table 4). Survey results identified that while approximately one-third of the community members eat only the fillet, many individuals identified eating the entire fish, and a significant proportion ate various parts of the fish including fillets, cheeks, livers, eggs and guts. In the case of sucker, all of the respondents indicated that the head of the sucker was used to make soup.

4. Toxicological reference values
Consistent with Health Canada (2007a) and Alberta Health (2016), it was assumed that all of the mercury in the fish was methyl mercury. The exposure point concentration for methyl mercury was calculated using the measured concentrations of mercury in the samples and was not modified to account for the fraction of inorganic mercury in the samples. In fish tissue, mercury is methylated and becomes more bioavailable in its organic form: methyl mercury. The toxicological reference values (TRVs) used in the assessment are presented in Table 5.

5. Consumption assessment
The concept of a hazard quotient (HQ) is used to determine non-carcinogenic risk. The HQ represents the relationship (ratio) between the magnitude of exposure to the contaminant of potential concern and a TRV, as follows:

\[ HQ = \frac{EDI}{TRV} \]

where \( TRV \) = toxicological reference value (mg/kg bw/day); \( EDI \) = estimated daily intake (mg/kg bw/day).

and where:

\[ EDI = \frac{C_{Fish} \times IR_{Fish} \times RAF_{Oral}}{BW} \]

where \( EDI \) = estimated daily intake (mg/kg bw/day); \( C_{Fish} \) = concentration of mercury in the fish tissue (mg/kg wwt); \( IR_{Fish} \) = ingestion (consumption) rate of fish tissue (kg wwt/day); \( RAF_{Oral} \) = relative absorption factor from the gastrointestinal tract (100% (1.0)); \( BW \) = body weight (kg) (70.7 kg; Health Canada, 2012).

Benchmark consumption quantities were calculated for both whole fish and the fish fillets using a HQ of 1.0. An HQ of 1.0 was used as methyl mercury in the diet comes almost exclusively from consumption of fish tissues (Alberta Health, 2016; WHO, 2008, WHO (World Health Organization), 2014). For comparison purposes, benchmark consumption rates were calculated using the 95th upper confidence limit of the mean methyl mercury concentration for adults (male and female) in the fillets and the maximum concentration in the whole fish and the Health Canada generic weight of 70.7 kg in conjunction with the appropriate TRVs. A portion size of 225 g/serving was used for adult males and a 150 g/serving was used for females (Health Canada, 2007b).

Therefore,

\[ \text{Benchmark Consumption Rate} = \frac{BW \times TRV \times HQ}{C_{Fish} \times RAF_{Oral}} \]
| Fish species        | Proportion of consumers who ate only the fillets | Proportion of consumers who ate the “entire fish” | Proportion of consumers who ate the fillet and other parts of the fish | Guts | Head | Eggs | Cheeks | Skin | Liver |
|--------------------|--------------------------------------------------|--------------------------------------------------|-----------------------------------------------------------------------|------|------|------|--------|------|-------|
| Pickerel (walleye) | 0.37                                             | 0.09                                             | 0.54                                                                  | 0.04 | 0.03 | 0.02 | 0.29    | 0.02 | 0.02  |
| Jackfish (pike)    | 0.30                                             | 0.30                                             | 0.39                                                                  | 0.25 | 0.03 | 0.09 | 0.06    | 0.06 | 0.06  |
| Mariah (burbot)    | 0.56                                             | 0.11                                             | 0.33                                                                  | 0.22 | 0.06 | 0.11 | 0.11    | 0.06 | 0.11  |
| Whitefish          | 0.47                                             | 0.32                                             | 0.20                                                                  | 0.08 | 0.01 | 0.07 | 0.04    | 0.06 | 0.03  |
| Sucker             | 0.00                                             | 0.00                                             | 1.00                                                                  | 0.00 | 1.00 | 0.00 | 0.00    | 0.00 | 0.00  |
Alberta Health (2016) provides fish consumption advisories for lakes where measured fish mercury concentrations are between 0.2 and 0.5 mg/kg. Advisories are calculated by Alberta Health for fillet consumption based on average measured concentrations in fish fillets. The mean mercury concentrations for fish collected from Hook Lake and Lesser Slave Lake were between 0.2 and 0.5 mg/kg for jackfish and pickerel fillets. There is currently a fish advisory in effect for Lesser Slave Lake.

As shown in Table 6, the benchmark consumption quantities for whole fish are higher compared to the benchmark consumption quantities calculated for fillets across all lakes and both fish species, which reflects the higher mercury concentrations measured in the fillets compared to the whole fish. The ratio of benchmark consumption quantities for whole fish vs. fillets ranges between 1.5 and 4.5 depending on the fish species and the lake. Caution, however, should be applied in the literal interpretation and application of these values as the amount of mercury consumed will vary by individual according to dietary preferences; and only a small proportion of the respondents consumed the “entire” fish. The small sample size of whole fish collected is also a limitation in the interpretation of the data although the mercury concentration finding was consistent across all of the lakes in the study. The incorporation of the fillet concentration in the Alberta Health (2016) methodology protects consumers against the maximum potential exposure.

6. Interpretation and discussion

Subsistence fishers need to be aware of the presence of mercury in fish tissues and the potential consumption limitations. Consumption of all components of a harvested animal is important to First Nations. For this reason, and through continuation of traditional dietary practices, the exposure to methyl mercury when consuming more than just the fillet may result in a lower average mercury exposure concentration. As methyl mercury is predominant in the fish muscle tissue, the consumption of other parts of the fish which have lower concentrations of methyl mercury (e.g. skin, eggs; Stantec, 2012) will reduce the amount of “mercury/gram” of food consumed (Gutenmann & Lisk, 1990). The amount and parts of the fish actually consumed influence the quantity of mercury consumed (R M, Brigham, & Stauffer, 1996).

While it is acknowledged that not all subsistence consumers eat the fish in its entirety, the recognition of traditional consumption practices resulting in a more accurate assessment of exposure risk should be considered in the development of fish consumption guidelines. As reviewed in McAuley and Knopper (2011), there are both positive and negative aspects to the issuance of consumption advisories. Some communities opt to continue with traditional consumption practices believing that the psychological, nutritional, economic and lifestyle benefits of doing so outweigh the risks of following advisories. Agencies need to ensure a balance between human health and maintenance of culture in the establishment of guidance. Given that between 20% and 100% of the consumers identified eating more than just the fillet, dependent upon fish species, the consideration of consumption of multiple parts of the fish in an assessment of exposure may provide a more accurate representation of risk. The reinforcement of the continued quality of the traditional foods may help avoid overly protective consumption guidelines that can have unnecessarily negative effects on the well-being of First Nations members (McAuley, Dersch, Kates, Sowan, & Olisson, 2016).
| Receptor          | Fish Species | Mercury concentration in fish [mg/kg] | Benchmark consumption [servings/wk] | Factor (whole/fillet) |
|------------------|--------------|--------------------------------------|------------------------------------|-----------------------|
|                  | Lake         | Fillet                               | Whole                               |                       |
|                  |              | Female (childbearing age)             | Live                               |                       |
| Hook Lake        | Jackfish     | 0.41                                 | 1.6                                 | 7.3                   | 4.5                   |
| Kirby Lake       | Jackfish     | 0.23                                 | 2.9                                 | 8.8                   | 4.8                   |
| Winefred Lake    | Jackfish     | 0.20                                 | 3.3                                 | 8.8                   | 4.8                   |
| Winefred Lake    | Pickerel     | 0.21                                 | 3.0                                 | 8.8                   | 4.8                   |
| Winefred Lake    | Jackfish     | 0.22                                 | 4.0                                 | 11                    | 4.5                   |
| Winefred Lake    | Pickerel     | 0.22                                 | 4.0                                 | 11                    | 4.5                   |
| Lesser Slave Lake| Jackfish     | 0.42                                 | 2.5                                 | 7.5                   | 4.5                   |
| Lesser Slave Lake| Pickerel     | 0.42                                 | 2.5                                 | 7.5                   | 4.5                   |
| Lesser Slave Lake| Jackfish     | 0.42                                 | 2.5                                 | 7.5                   | 4.5                   |
| Lesser Slave Lake| Pickerel     | 0.42                                 | 2.5                                 | 7.5                   | 4.5                   |
| Adult            | Hook Lake    | 0.41                                 | 4.5                                 | 14                    | 6.8                   |
| Kirby Lake       | Jackfish     | 0.23                                 | 10                                  | 14                    | 6.8                   |
| Winefred Lake    | Jackfish     | 0.21                                 | 10                                  | 14                    | 6.8                   |
| Winefred Lake    | Pickerel     | 0.21                                 | 10                                  | 14                    | 6.8                   |
| Lesser Slave Lake| Jackfish     | 0.42                                 | 24                                  | 55                    | 22                    |
| Lesser Slave Lake| Pickerel     | 0.42                                 | 24                                  | 55                    | 22                    |
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Competing interests
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Ethics statement
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