Keeyask Generation Project

Aquatic Effects Monitoring Plan

Mercury in Fish Flesh from the Aiken River in 2015 Report

AEMP-2016-10

KEEYASK

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KEEYASK GENERATION PROJECT

AQUATIC EFFECTS MONITORING REPORT

Report #AEMP–2016-10

MERCURY IN FISH FLESH FROM THE AIKEN RIVER IN 2015

Prepared for

Manitoba Hydro

By

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SUMMARY

Background

The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the Keeyask Generating Station (GS) on the environment. Besides measuring the accuracy of the predictions made and actual effects of the GS on the environment, monitoring results will provide information on how construction and operation of the GS will affect the environment and if more needs to be done to reduce harmful effects.

Construction of the Keeyask GS began in mid-July 2014. During August and September, the flow in the north and central channels of Gull Rapids was blocked off and all the flow was diverted to the south channel. Cofferdams were constructed in the north and central channels and these channels were dewatered by fall (see construction site map below). The combination of high natural flows in the Nelson River and diversion of flow resulted in water levels on Gull Lake increasing about 1.3 m at the water level monitoring site at Caribou Island. The rise in water levels resulted in flooding along the shoreline and in low-lying areas. During the winter, a cofferdam was constructed extending into the south channel. During the spring of 2015, flows in the Nelson River decreased and water level on Gull Lake went down to pre-construction high water levels.

Fish mercury is one of the key components for monitoring because it affects the suitability of fish for consumption by people. Flooding of the Keeyask reservoir is predicted to increase mercury levels in fish in Gull and Stephens lakes, though the increase in Stephens Lake will be much less than when the lake was first created by construction of the Kettle GS in the early 1970s. The average concentration of mercury in fish in upstream waterbodies such as Split Lake and the Aiken River could be affected if a large proportion of the fish in these waterbodies also spend extended periods in the Keeyask reservoir. Given that fish moving out of the Keeyask reservoir are expected to form only a small proportion of the fish in Split Lake and the Aiken River, no measurable effects to average mercury concentrations of fish collected from these waterbodies are predicted. Sampling is being conducted to confirm this prediction.

This report provides mercury concentrations measured in jackfish and pickerel from the Aiken River near York Landing and Ilford in 2015. Fish samples collected at this time represent pre-construction conditions because the flooding that began in mid-July 2014 at Gull Lake could not have affected the average mercury level in these large-bodied fish coming to spawn in the Aiken River in spring 2015, as there is a delay between flooding and when mercury begins to accumulate in measureable amounts in the flesh of large-bodied fish.

Map of instream structures at the Keeyask Generating Station site, June 2015.

Why is the monitoring being done?

The monitoring in 2015 was done to answer the following questions:

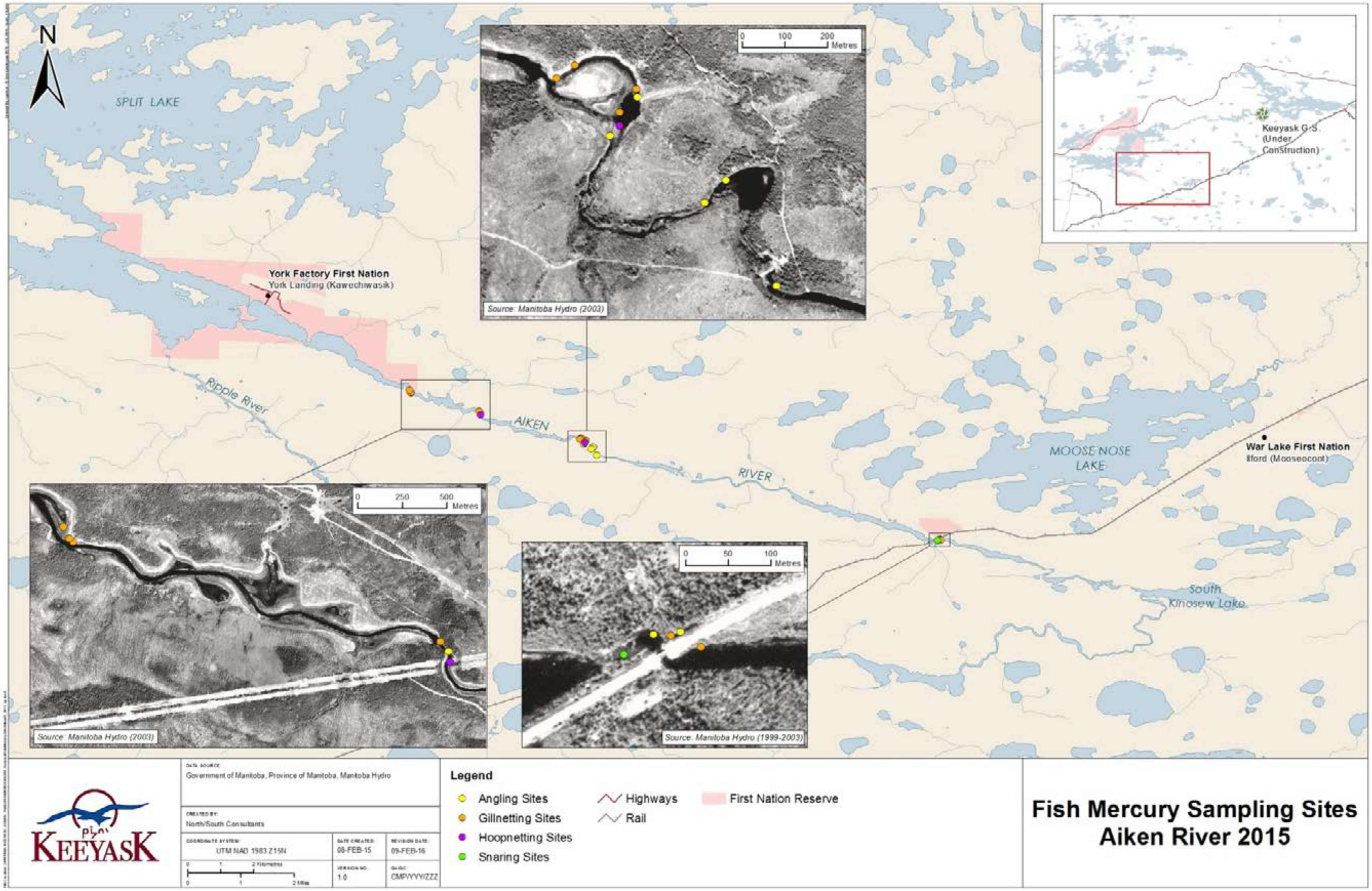
- What are mercury concentrations in jackfish and pickerel, two domestically and commercially important species, before any potential effects due to the Keeyask Project (*e.g.*, by fish moving from the Keeyask reservoir to the Aiken River)?
- Have mercury concentrations in jackfish and pickerel remained unchanged at two locations on the Aiken River (York Landing and Ilford) in 2015 compared to previous study years?

What was done?

Jackfish and pickerel were captured from the Aiken River near York Landing and Ilford in May 2015 (see map of the Aiken River below). Approximately 35 fish of each species were taken from each location. Fish were measured for length and weight and a structure to determine the fish's age was collected. A piece of muscle was taken from each fish for mercury analysis. Mercury was measured at a certified laboratory in Winnipeg.

Using the mercury concentration measured in each fish, the average mercury concentration of all fish from each species (pickerel or jackfish) and location (York Landing or Ilford) was calculated. This concentration is referred to as the arithmetic mean. Because the concentration of mercury in fish typically increases with the length of the fish, a second value was calculated that adjusts the concentration to a standard fish length (400 mm for pickerel, 550 mm for jackfish). This value is called the standard mean. Comparison of mercury concentrations between years and waterbodies based on a standard mean is more reliable than the arithmetic mean since the standard mean accounts for differences in the size of fish sampled each year. Standard means can only be calculated if the fish that were sampled show an increase in mercury concentration with fish length. Therefore a standard mean is not always available.

Frozen pickerel muscle sample being prepared for mercury analysis.



Map of the Aiken (Landing) River showing sampling sites for fish mercury in 2015.

What was found?

Standard means of fish collected from the Aiken River at York Landing and Ilford in 2015 ranged from 0.35–0.36 ppm in jackfish and were 0.30 ppm in pickerel captured at Ilford. No standard mean could be calculated for pickerel from York Landing but the arithmetic mean was 0.28 ppm.

A comparison of the results for 2015 with past results shows that:

- Mercury concentrations in 2015 are similar to concentrations measured in 2009 and 2012, the last two times the Aiken River was sampled; and
- Standard mean mercury concentrations in 2015 were mostly statistically higher than concentrations measured during the studies for the EIS (2002 to 2006).

Freshly caught jackfish awaiting processing for muscle samples for mercury analysis.

Pickerel spawning habitat in the Aiken River upstream of York Landing.

What does it mean?

Mercury concentrations measured over the past nine years have been relatively constant but are statistically significantly higher than measured during the studies for the environmental assessment of the Keeyask GS. This means that mercury concentrations can change due to factors in the environment, not necessarily related to a specific development.

What will be done next?

Fish mercury concentrations from the Aiken River at York Landing and Ilford will be monitored again in three years according to the schedule in the Keeyask AEMP.

ACKNOWLEDGEMENTS

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The collection of biological samples described in this report was authorized by Manitoba Conservation and Water Stewardship, Fisheries Branch, under terms of the Scientific Collection Permit #17-15 (Aiken River 2015).

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1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt (MW) hydroelectric generating station currently under construction northern Manitoba. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS (Map 1).

The *Keeyask Generation Project: Response to EIS Guidelines*, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume* (AE SV). As part of the licencing process for the Project, an Aquatic Effects Monitoring Plan (AEMP) was developed detailing the monitoring activities of various components of the aquatic environment for the construction and operation phases of the Project.

Fish mercury is one of the key components for monitoring because it affects the suitability of fish for consumption by people. Flooding of the Keeyask reservoir is predicted to increase mercury levels in fish in Gull and Stephens lakes, though the increase in Stephens Lake will be much less than when the lake was first created by construction of the Kettle GS in the early 1970s. The average concentration of mercury in fish in upstream waterbodies such as Split Lake and the Aiken River could be affected if a large proportion of the fish in these waterbodies also spend extended periods in the Keeyask reservoir. Given that fish moving out of the Keeyask reservoir are expected to form only a small proportion of the fish in Split Lake and the Aiken River, no measurable effects to average mercury concentrations of fish collected from these waterbodies are predicted. Sampling is being conducted to confirm this prediction.

The waterbodies included in the fish mercury component of the AEMP are Gull Lake/Keeyask reservoir, Stephens Lake, Split Lake, and the Aiken River, a tributary of Split Lake. In the event that mercury concentration in fish from Stephens Lake should exceed predicted maximum concentrations by more than 10%, the fish mercury monitoring program will be extended further downstream on the Nelson River by sampling within the Long Spruce Forebay.

This report provides results for mercury monitoring in Northern Pike (*Esox lucius*) and Walleye (*Sander vitreus*) collected in spring 2015 from the Aiken River. Mercury data from these two piscivorous species in the Aiken River were first collected during environmental studies for the Project in 2002 and 2003, and some more limited data are also available from earlier years. In response to War Lake First Nation (WLFN) and York Factory First Nation (YFFN) members' concerns with respect to mercury in fish flesh, a study was initiated in 2006 to monitor mercury concentrations in Northern Pike and Walleye on a three-year cycle until such time as there was (or was not) an indication of change.

The monitoring in 2015 was done to answer several questions:

- What are mercury concentrations in Northern Pike and Walleye before any potential effects due to the Keeyask Project (*e.g.*, by fish moving from the Keeyask reservoir to the Aiken River)?
- Are mercury concentrations in these two species in 2015 unchanged from previous measurements?
- How do recent mercury concentrations compare to benchmarks established in the AEMP?

Results from post-EIS fish mercury sampling in 2009 and 2012 have been reported in Jansen (2010a) and Jansen (2012), respectively. The current report will build upon the 2002 to 2012 timeline of fish mercury concentrations, adding results from the 2015 sampling.

For ease of reading, Northern Pike is also referred to as pike in this report.

2.0 METHODS

2.1 FIELD COLLECTIONS

The 2015 sampling program was conducted using methodologies similar to those used in previous sampling programs conducted between 2002 and 2012. Northern Pike and Walleye were collected from two, general areas in the Aiken River: near the communities of York Landing and Ilford (in the following referred to as “from” or “at” York Landing/Ilford).

Pike and Walleye were collected for mercury analysis from several sites at York Landing from May 22 to 25, 2015 and at Ilford from May 20 to 22, 2015 (Map 2). At both locations, pike and Walleye were captured using single panel gill nets measuring 25 yards (22.9 m) long by 6 feet (1.8 m) deep with (stretched) mesh sizes of 2, 3, or 4.25 inch (51, 76, 108 mm). In addition, fish were captured in large (1.2 m hoop diameter, 2.5 cm mesh) hoop nets, by angling, and by snaring (1 Walleye). Hoop nets set in the Aiken River at both locations were set overnight and gill nets were either pulled or checked every two hours.

To be consistent with the methodology described in earlier Manitoba fish mercury monitoring programs (Jansen and Strange 2007), a broad size range of fish was collected. A tally of the fish captured within each consecutive 50 mm length interval (starting at 100 mm) was kept aiming for an equal distribution of lengths classes within a target size of 36 fish per species. Upon capture, large-bodied fish were measured for fork length (±1 mm) and total weight. Weight was recorded to ±25 g on a pan balance. Fish were also examined internally to determine sex and maturity, and bony structures were removed for age analysis: dorsal spines were taken from Walleye, and cleithra were collected from Northern Pike. A portion of axial muscle weighing between 10 and 40 g was removed from each fish anterior to the caudal (tail) fin for mercury analysis. The muscle with skin attached was wrapped tightly with commercial “cling-wrap”, placed in a mercury-free, internally and externally labelled Whirl-Pac bags or Zip-lock bags, and stored on ice until it could be frozen. Frozen tissue samples were shipped to the North/South office in Winnipeg for inventorying, storage, and further processing.

2.2 LABORATORY DETERMINATIONS

Frozen tissue samples were shipped to the ALS Laboratory Group laboratory in Winnipeg considering a holding time requirement between fish capture and analysis of less than one year. The 2015 Aiken River samples were analyzed for mercury between November 4 and 19, 2015. The skin on the one side of the muscle sample and a thin surface layer of the exposed muscle tissue on the opposite side was sliced away before the remaining sample was homogenized (see below). This procedure helped to ensure that the percentage of water in the muscle sample was representative of the original sample taken from the fish.

Mercury analysis was performed using an adaptation of US EPA Method 200.3 "Sample Procedures for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues". In preparation, tissue samples were homogenized and sub-sampled prior to “HotBlock” digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis was by atomic fluorescence spectrophotometry, adapted from US EPA Method 245.7.

Samples of two different standard (certified) reference materials (SRM) were typically analyzed with each sample run (Table 1):

- apple leaves (https://www-s.nist.gov/srmors/certificates/archive/ 1515.%20July%202,%201991.pdf; last accessed 7 February, 2016;
- lobster hepatopancreas (TORT-3; National Research Council Canada, NRC; http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/tort_3.html;last accessed 27 January, 2016); and
- fish protein (DORM-4; NRC; http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/ certificates/ dorm_4 .html; last accessed 27 January, 2016).

In addition, several replicate analyses of the homogenate of submitted fish tissues samples were also run for quality control purposes. Mean mercury concentrations obtained from the SRMs were within 17% of the mean certified value for TORT-3 and 24% for DORM-4 (Table 1). The mean percentage deviation of replicate homogenate analyses was 4.1% with a range of 0–7.4% (Table 1).

Dried ageing structures of all fish were prepared and analyzed using a variety of techniques. Walleye dorsal spines were coated in epoxy and sectioned with a Struers microtome saw. Sections were then fixed on glass slides with Cytoseal 280 and fish ages were determined by examining the slides with a Wild M3 dissecting microscope. Pike cleithra were cleaned and examined under reflected light.

2.3 DATA ANALYSIS

A condition factor (K) was calculated for each fish as:

$$K = W \times 10^5 / L^3$$

where: W = total weight (g); and

L = fork length (mm).

Fish obtained in different years from a group of lakes will invariably differ in mean size between years and lakes. Because fish accumulate mercury over their life time, older and, normally, larger individuals have higher levels than younger, smaller fish (Green 1986; Evans *et al*. 2005).

In addition to calculating arithmetic mean mercury concentrations (also referred to as arithmetic means), mean mercury concentrations have been standardized to a common fish length under earlier Manitoba fish mercury monitoring programs (Jansen and Strange 2007) and CAMP (CAMP 2014) to facilitate comparisons for the same species of fish between years from one waterbody or between different waterbodies in a given year. The standard lengths used for Northern Pike and Walleye were 550 and 400 mm, respectively.

Length standardized mean mercury concentrations (also referred to as standard means) were calculated from unique regression equations, by species and river location, based on the analysis of logarithmic transformations of muscle mercury concentration and fork lengths using the following relationship:

$$Log_{10}[Hg] = a + b\ (Log_{10} L)$$

where: [Hg] = muscle mercury concentration (µg/g or ppm);

L = fork length (mm);

a = Y-intercept (constant); and

b = slope of the regression line (coefficient).

To present data in more familiar units, all standard means and their measures of variance presented in the tables and figures have been retransformed to arithmetic values.

Because one of the objectives of the 2015 sampling program was to evaluate potential changes in mercury concentrations in fish from the Aiken River over time, the results for 2015 were compared to data collected in previous years.

Differences in mean length, weight, and age of fish species between locations (and years) were ascertained employing one-way and two-way analysis of variance (ANOVA). If F-values were significant, differences between individual means were confirmed by Holm-Sidak's pairwise multiple comparison tests. If normality of data distribution or equality of variances could not be achieved by logarithmic transformation of the data, Kruskal-Wallis one-way ANOVA on ranks was performed, applying Dunn's method for pairwise multiple comparisons. In all cases, significance was established at $p \leq 0.05$. Actual probabilities values are stated in the text if $p < 0.05$. Differences in standardized mean mercury concentrations between locations or years were established if the 95% confidence limits (CL) of two means did not overlap. Statistical analyses were completed using Sigma Plot V 11.0 (SSI 2008) and the plyr package version 1.8 (Wickham 2011) for R Version 2.15.0 (R Development Core Team 2012).

2.4 BENCHMARKS

The Keeyask AEMP identified the following benchmarks for comparison with monitored fish mercury concentrations from Project area waterbodies:

- The 0.5 ppm total mercury Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a, b), which also represents the Manitoba guideline for mercury in fish for the protection of human consumers (MWS 2011).
- A 0.2 ppm total mercury guideline instituted as a “safe consumption limit” for people eating “large quantities of fish” for subsistence purposes (Wheatley 1979); and
- The 0.033 ppm methylmercury Canadian and Manitoba tissue residue guidelines of for the protection of wildlife consumers of aquatic biota (CCME 1999 with more recent updates; MWS 2011)

Whereas the 0.5 ppm standard applies to the suitability of fish for commercial marketing in Canada (*i.e.*, the general public consuming store-bought fish), the 0.2 ppm guideline was established to provide practical advice to people who frequently consume wild fish. However, Health Canada no longer uses the 0.2 ppm guideline for unrestricted domestic consumption. Instead, the agency uses the provisional Tolerable Daily Intake (TDI) of 0.47 µg methylmercury per kilogram of body weight per day (kg-bw/day) for adults, and 0.2 µg methylmercury per kg-bw/day for women of childbearing age (Health Canada 2010) in human health risk assessments. The TDI approach does not result in a simple number for a fish mercury concentration as the exposure to mercury varies both with the human consumer and with the amount, species and size of fish consumed. Therefore, the TDI approach does not provide a benchmark suitable for use in environmental effects monitoring when only (mean) fish mercury concentrations for a particular year are available for the assessment. To address questions regarding suitability of fish for human consumption, data collected by this fish mercury monitoring study is being provided to the Mercury and Human Health Implementation Group, established by the KHLP. One of the tasks of this group is to develop consumption guidelines based on mercury concentrations in locally caught fish for people who consume large amounts of fish.

Since selecting the 0.033 ppm benchmark guideline for the protection of wildlife consumers of aquatic biota for the EIS, the Canadian Council of Ministers of the Environment has ceased the development of further tissue residue guidelines for the protection of wildlife consumers of aquatic biota (N. Burgess, pers. comm. 2015), as their guideline will be exceeded by a substantial portion of fish from lower trophic levels and almost all adult predatory fish routinely monitored in Manitoba (CAMP 2014) and elsewhere in Canada (Depew *et al*. 2013). For this reason, the tissue residue guideline of 0.033 ppm methylmercury for the protection of wildlife consumers of aquatic biota that was originally selected is no longer an appropriate benchmark to use for the Keeyask Generation Project.

Given that the 0.2 ppm and 0.033 guidelines are no longer supported by the agencies that identified them, only the 0.5 ppm Health Canada standard for the commercial marketing of fish will be used as a benchmark for the assessment of fish mercury concentrations in the AEMP.

3.0 RESULTS

3.1 SAMPLE DESCRIPTION AND BIOLOGICAL DATA

Mercury concentrations were obtained from 72 Northern Pike and 73 Walleye caught in the Aiken River in 2015. The target sample size of 36 fish of each species caught was achieved at both York Landing and Ilford. Except for one pike from York Landing, all fish analyzed for mercury were aged (Table 2).

Mean length, weight, condition, and age of Northern Pike and Walleye analyzed for mercury were mostly similar between the two sampling locations (Table 2). Only pike from York Landing were significantly (P = 0.02) longer than their conspecifics captured at Ilford. Similar, statistically significant differences in pike length have consistently been found in previous sampling years (*i.e.*, 2006, 2009, and 2012). In contrast to the three previous sampling years, Walleye condition did not differ significantly between Ilford and York Landing in 2015. Identical to results obtained for 2012, but unlike for 2006 and 2009, Walleye from the two locations were of similar age in 2015. Pike age also did not statistically differ between fish caught at Ilford and York Landing. However, age differed significantly between the two species captured at each location with Walleye being approximately one year older than pike.

The mean length of pike from York Landing was slightly higher than the standard length for the species (550 mm), whereas pike from Ilford were almost 29 mm smaller than the standard length (Table 2). Walleye selected for mercury analysis from York Landing were also larger than the standard length for the species (400 mm), whereas the mean length of their conspecifics from Ilford exactly corresponded to the standard length. Biological data for individual fish are presented in Appendix 1.

3.2 MERCURY CONCENTRATIONS

3.2.1 RESULTS FOR 2015

Length standardized mean mercury concentrations of fish collected from the Aiken River in 2015 ranged from 0.35–0.36 ppm in Northern Pike and were 0.30 ppm in Walleye captured at Ilford (Table 3). The relationship between mercury concentration and fish length was not significant for Walleye from York Landing, and a standard mean could not be calculated; the arithmetic mean was 0.28 ppm. Standard means were statistically similar for pike captured at the two locations. Arithmetic means of pike and Walleye were also similar between sampling locations. The similarity in the results for standard means and arithmetic means for each species and location reflects the similarity of the mean lengths of the sampled fish and the respective standard lengths (see Section 4.1).

When comparing mercury concentrations between the two species, arithmetic means of pike captured at York Landing were significantly ($p = 0.001$) higher than those of Walleye, whereas both species had similar mercury concentrations at Ilford.

The standard means and arithmetic means of pike and Walleye from both locations were below the 0.5 ppm Health Canada standard for commercial sale of fish. However, considering mercury concentrations of individual fish, 39% and 25% of all pike from York Landing and Ilford, respectively, exceeded a concentration of 0.5 ppm, reaching maxima of 0.85 ppm and 0.78 ppm (Figure 1). One Walleye from York Landing and two from Ilford (*i.e.*, 3% and 6% of the total sample, respectively) had mercury concentrations that exceeded the Health Canada standard (Figure 1).

Mercury concentrations for individual fish are presented in Appendix 1.

3.2.2 COMPARISONS TO OTHER YEARS

Walleye and pike from the Aiken River at Ilford have been analyzed for mercury since 1978 (Figure 2). However, until 2002 sample sizes have always been small (3–8 fish) for both species and only in two cases has the relationship between fish length and mercury concentration been significant during this time period. Except for the relatively small samples of pike and Walleye from the Aiken River at York Landing in 1982, data on fish mercury concentrations from this location only exist since 2003 (Figure 2). Although mercury concentrations for pike and/or Walleye from Ilford have been available for 10 years from 1978–1998, sample sizes have been very small and only two standard means could be calculated. Considering these limitations, concentrations in pike and Walleye from York Landing and Ilford have been relatively low (< 0.27 ppm) between 1993 and 2006 and standard means in 2006 (0.19–0.26 ppm) were the lowest or second lowest (Walleye from Ilford) for the entire record. Concentrations then increased in both species from the two locations from 2006 to 2009 (0.27–0.34 ppm). These increases were significant except for the small sample of pike collected at Ilford in 2009. Standard means of Walleye have remained significantly higher compared to 2006 until 2015 at both locations (Figure 2). Furthermore, pike captured at Ilford in 2015 had significantly higher mercury concentrations than their conspecifics from Ilford in 2006. Standard means of the two piscivors from both locations were statistically similar in years 2009, 2012, and 2015.

In addition to the above temporal and spatial patterns, there also existed some differences in mercury concentrations between the two species captured from the Aiken River. Arithmetic means of pike from York Landing were usually higher compared to Walleye from York Landing, (Figure 2). With the single exception of 2012, arithmetic mean concentrations in pike captured at Ilford were always higher than those of Walleye from Ilford for all 12 common sampling years.

4.0 DISCUSSION

Pike and Walleye from the two locations on the Aiken River have maintained a significant increase in mercury concentrations over 2006 levels for samples collected in 2009, 2012, and 2015. There were no significant changes in mercury concentrations among these three time periods. This is in contrast to their conspecifics from Split Lake which showed a transient but significant decrease in concentration in 2010 after the large and significant increase from 2005 to 2007 (Manitoba Hydro and the Province of Manitoba 2015). Although concentrations in pike and Walleye from Split Lake are currently (most recent sample in 2013; CAMP, unpubl. data) again significantly higher than they were in 2005, the slight difference in the temporal pattern in fish mercury compared to the Aiken River is surprising. Although direct evidence is lacking, it can be assumed that most, if not all of the pike and Walleye captured during spawning time in the Aiken River moved upstream from Split Lake and could be expected to have experienced similar long-term conditions of mercury availability compared to their conspecifics that were sampled in Split Lake. Potential explanations for these spatial differences in fish mercury concentrations include between-year (*i.e.*, fish from the Aiken River and Split Lake were not sampled in the same years) and between-site variability. Spatial variation in fish mercury concentrations has been documented in lakes (Cizdziel *et al*. 2002; Chumchal *et al*. 2008; Simoneau *et al*. 2005) and rivers (Choy *et al*. 2008) and has been attributed to heterogeneity in mercury availability (see discussion in Chumchal *et al*. 2008). The results from the Aiken River further suggest that spawning site fidelity may also contribute to geographical differences in mercury concentrations. For the past four sampling years, when samples were relatively large and standard means could be calculated, Walleye captured near their spawning sites at Ilford had consistently higher mercury concentrations than their conspecifics collected from York Landing, and in 2006 and 2012 the difference was significant.

Despite the increased concentration over the past nine years, the standard means and arithmetic means of pike and Walleye from both locations have remained below the 0.5 ppm Health Canada standard for commercial sale of fish. However, considering mercury concentrations of individual fish, 39% and 25% of all pike from York Landing and Ilford, respectively, exceeded a concentration of 0.5 ppm.

5.0 CONCLUSION AND NEXT STEPS

The key questions to be answered about mercury in fish in relation to the mercury in fish monitoring completed in 2015 were:

- *What is the concentration of mercury in Northern Pike and Walleye caught in the Aiken River prior to reservoir flooding and how has it changed since it was measured for the Keeyask EIS?*

  Sampling conducted in 2015 indicated that Northern Pike and Walleye mercury concentrations in the Aiken River at both York Landing and Ilford have shown no significant change over the last three sampling periods (2009, 2012, and 2015), but are significantly higher than concentrations reported in 2002, 2003, and 2006 (*i.e.*, in the EIS).

- *How do the 2015 mercury concentrations in jackfish and pickerel from the Aiken River compare to Health Canada's guideline for the commercial marketing of fish?*

  The standard means and arithmetic means of pike and Walleye from both locations were below the 0.5 ppm Health Canada standard for commercial sale of fish; however, mercury concentrations of individual fish exceeded 0.5 ppm.

  Mercury concentrations in Northern Pike and Walleye will be sampled again in the Aiken River at York Landing and Ilford in 2018.

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TABLES

Table 1: Comparison of total mercury concentrations (ppm; mean ± expanded uncertainty[1]) of certified reference materials (SRM): lobster hepatopancreas (TORT-3; National Research Council Canada, NRC), and fish protein (DORM-4; NRC) with results obtained by ALS Environmental in Winnipeg in conjunction with fish muscle analyses for the Aiken River in 2015; RPMD represents the relative percentage difference between the sample mean and the SRM mean; Replicates refers to the percentage difference between first and second sample of replicate analyses of muscle sample digests.

Statistic	TORT-3	DORM-4	Replicates
	(0.292 ± 0.022) [2]	(0.41 ± 0.055) [3]	(% difference)
Mean	0.247	0.322	4.1
Range	0.224–0.263	0.305–0.336	0.0–7.4
n [4]	8	7	7
RPMD (%)	17.3	24.0	n/a

1. expanded uncertainty is the sum of a (5% confidence limit and an allowance for systematic error between analytical methods and/or sample variation (*i.e.*, batches, bottles).
2. see http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/tort_3.html; last accessed 27 January, 2016.
3. see http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/crm/certificates/dorm_4.html; last accessed 27 January, 2016.
4. n represents the number of analyses.

Table 2: Mean (± SE) fork length, round weight, condition factor (K), and age of Northern Pike and Walleye from two locations on the Aiken River (AR) in 2015. Data to change.

Species	Waterbody	Length (mm)	n	Weight (g)	n	K	n	Age (years)	n
Northern Pike	AR, York Landing	566.6 ± 15.4	36	1284.7 ± 86.3	36	0.68 ± 0.01	36	5.5 ± 0.2	35
	AR, Ilford	521.5 ± 10.5	36	1011.1 ± 58.5	36	0.69 ± 0.01	36	5.3 ± 0.1	36
Walleye	AR, York Landing	415.8 ± 7.7	36	781.3 ± 43.2	36	1.05 ± 0.02	36	6.2 ± 0.2	36
	AR, Ilford	400.2 ± 6.0	37	708.1 ± 35.3	37	1.08 ± 0.01	37	6.4 ± 0.1	37

Table 3: Mean arithmetic (± SE) and standardized (95% confidence limits, **CL) mercury concentration (ppm) of Northern Pike and Walleye from two locations on the Aiken River (AR) in 2015.**

Species	Waterbody	n	Arithmetic	SE	Standard	95% CL
Northern Pike	AR, York Landing	36	0.431	0.033	0.364	0.324–0.409
	AR, Ilford	36	0.351	0.033	0.348	0.285–0.425
Walleye	AR, York Landing	36	0.280	0.016	- [1]	0.247–0.313
	AR, Ilford	37	0.307	0.014	0.299	0.279–0.322

1. The regression of mercury concentration and fish length was not significant; the 95% CL is for the arithmetic mean.

FIGURES

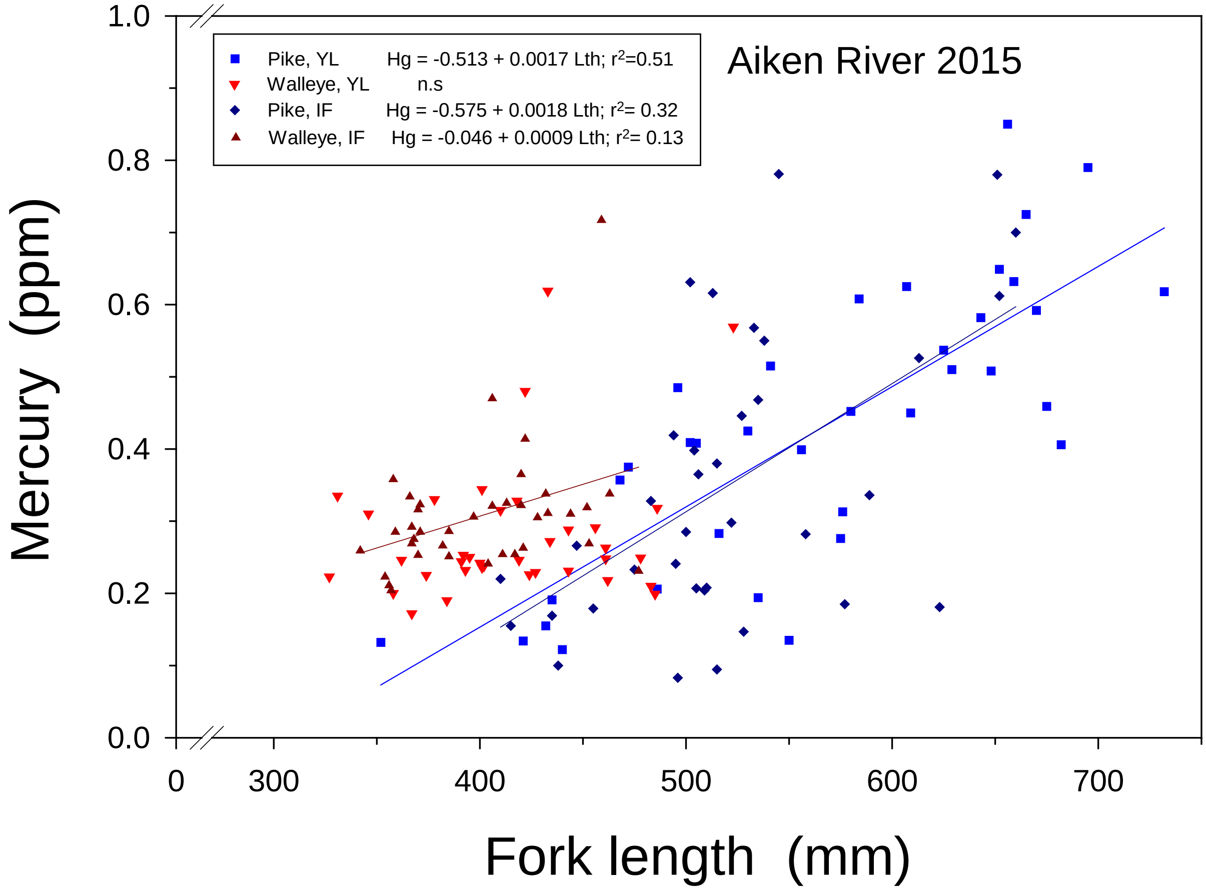
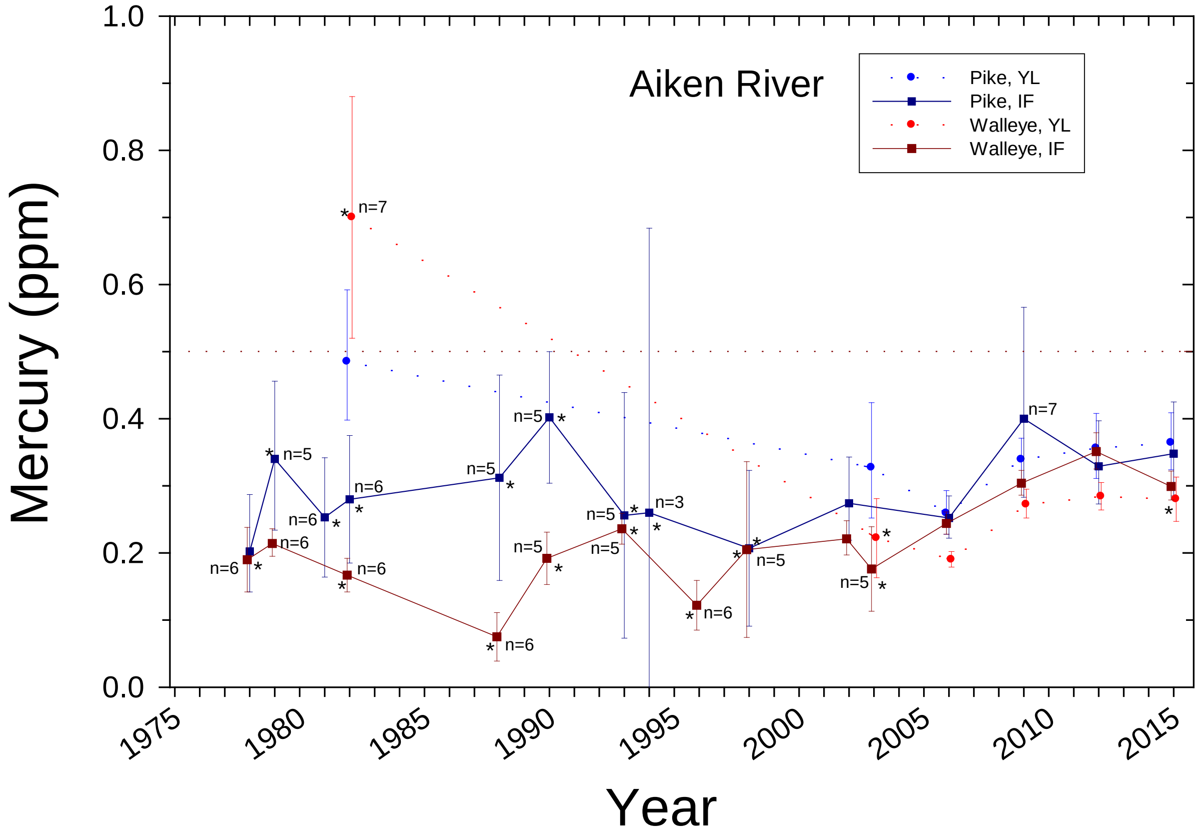


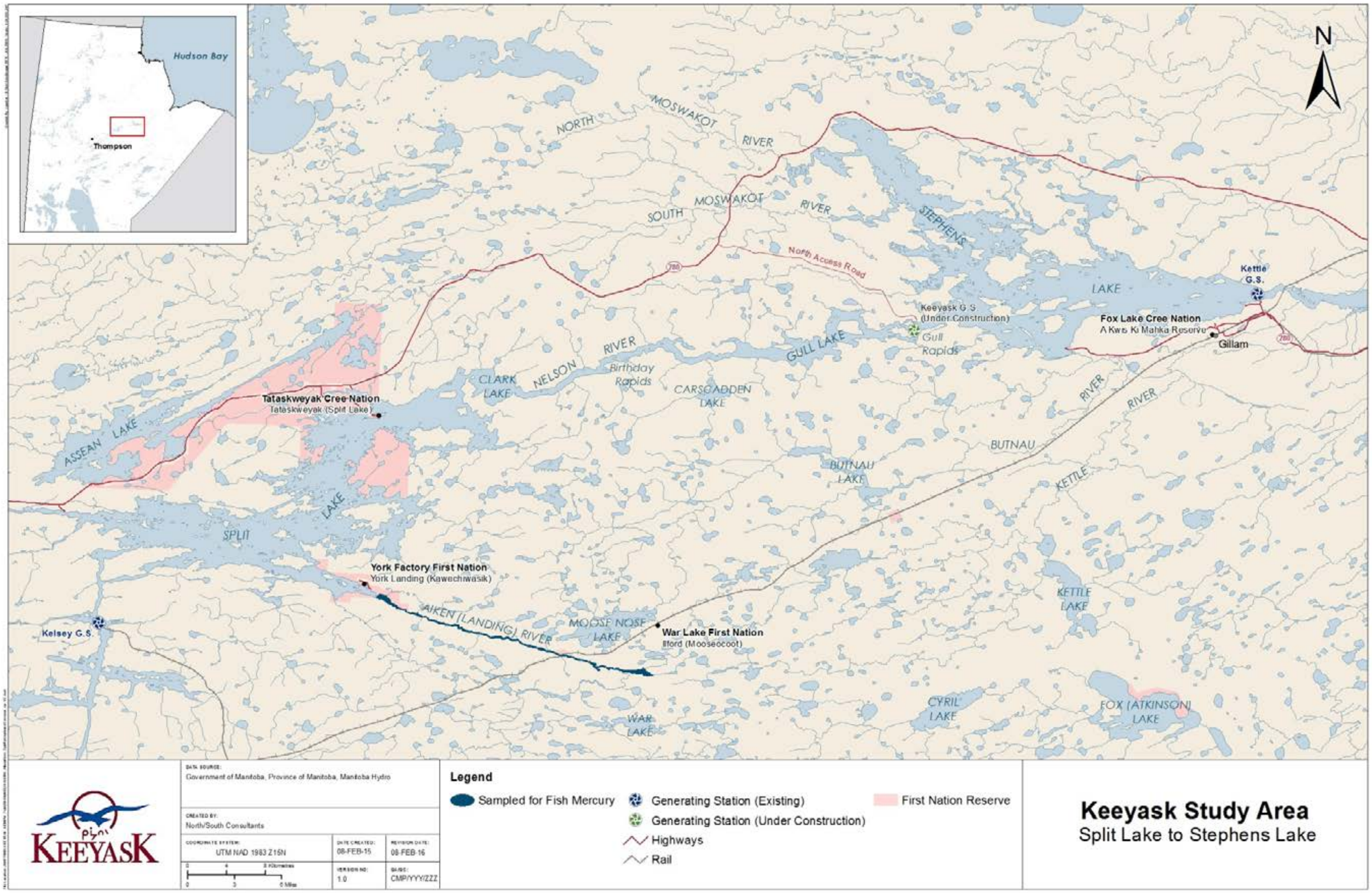
Figure 1: Relationship between mercury concentration and fish length for Northern Pike and Walleye captured from the Aiken River at York Landing (YL) and Ilford in May 2015. Significant regression lines are shown.



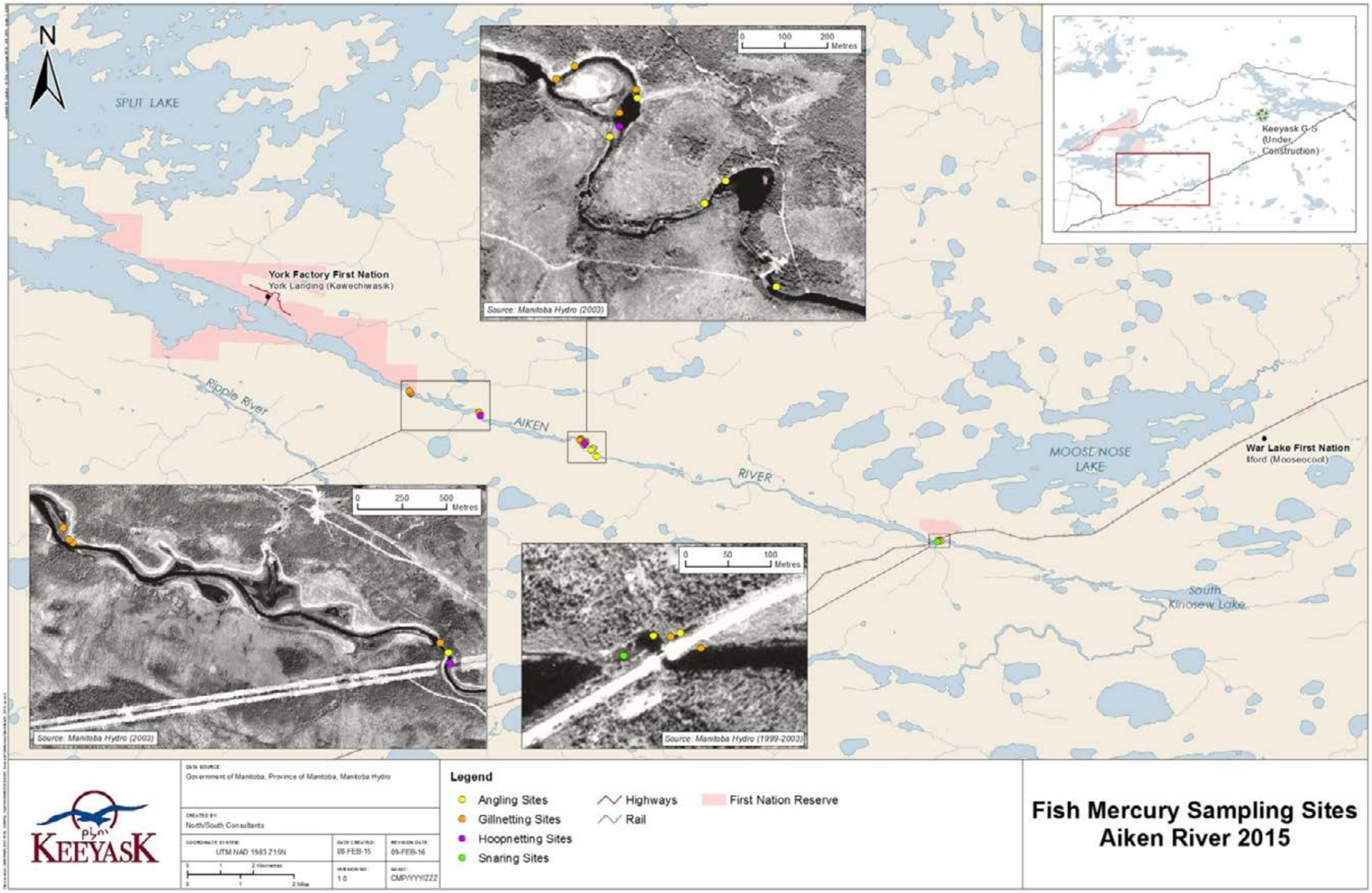
An asterisk indicates that the relationship between fish length and mercury concentration was not significant and the arithmetic mean was used; n represents sample size. The stippled line indicates the 0.5 ppm Health Canada standard.

Figure 2: Mean (95% confidence limits, CL) length standardized muscle mercury concentrations of Northern Pike and Walleye from the Aiken River at York Landing (YL) and Ilford (IF) for years 1978–2015.

MAPS



Map 1: **Map of the Keeyask study area showing hydroelectric development and highlighting the Aiken River.**



Map 2: Map of the Aiken (Landing) River showing sampling sites for fish mercury in 2015.

APPENDICES

APPENDIX 1: MUSCLE MERCURY CONCENTRATIONS AND BIOLOGICAL DATA FOR FISH FROM THE AIKEN RIVER IN 2015

Table A1-1: Definitions of codes used in Appendix tables.

Term	Code	Definition
Date		Sampling date
Species	NRPK	Northern Pike
	WALL	Walleye
Sex	F	Female
	M	Male
Maturity (Mat)	0	Immature
	1	Mature
Length		Fork length
Weight		Round weight
K		Condition factor

Table A1-2. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2015.

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
YL-01	2015	22-May	ANG-3	NRPK	432	575	0.713	Female	0	4	0.155
YL-02	2015	22-May	ANG-3	NRPK	530	1150	0.772	Male	1	5	0.425
YL-03	2015	22-May	ANG-3	NRPK	496	875	0.717	Male	1	5	0.485
YL-04	2015	22-May	ANG-4	NRPK	352	400	0.917	Female	0	3	0.132
YL-05	2015	22-May	ANG-4	NRPK	648	1675	0.616	Female	1	6	0.508
YL-06	2015	22-May	ANG-4	WALL	418	750	1.027	Female	1	6	0.328
YL-07	2015	22-May	ANG-3	NRPK	609	1425	0.631	Male	1	-	0.450
YL-08	2015	22-May	ANG-3	NRPK	516	950	0.691	Female	1	4	0.283
YL-10	2015	22-May	ANG-4	NRPK	675	2100	0.683	Female	1	7	0.459
YL-11	2015	22-May	ANG-4	WALL	461	950	0.970	Female	1	6	0.248
YL-12	2015	22-May	ANG-5	NRPK	652	1650	0.595	Male	1	7	0.649
YL-14	2015	22-May	ANG-5	NRPK	659	1550	0.542	Female	1	7	0.632
YL-16	2015	23-May	GN-3	NRPK	643	1900	0.715	Female	1	8	0.582
YL-17	2015	23-May	GN-4	NRPK	732	2400	0.612	Female	1	6	0.618
YL-18	2015	23-May	GN-4	NRPK	575	1150	0.605	Female	1	5	0.276
YL-19	2015	23-May	GN-3	NRPK	682	1950	0.615	Male	1	6	0.406
YL-20	2015	23-May	GN-3	NRPK	535	1125	0.735	Female	1	4	0.194
YL-21	2015	23-May	GN-6	NRPK	629	1750	0.703	Male	1	7	0.510
YL-22	2015	23-May	GN-6	NRPK	486	875	0.762	Male	1	5	0.206
YL-23	2015	23-May	GN-6	NRPK	580	1175	0.602	Female	1	6	0.452
YL-24	2015	23-May	GN-6	NRPK	440	600	0.704	Female	0	4	0.122
YL-25	2015	23-May	GN-6	NRPK	670	1800	0.598	Male	1	6	0.592
YL-26	2015	23-May	GN-6	NRPK	435	600	0.729	Male	1	5	0.191
YL-28	2015	23-May	GN-6	NRPK	584	1300	0.653	Female	1	5	0.608
YL-29	2015	23-May	GN-6	NRPK	550	1200	0.721	Female	1	5	0.135

Table A1-2. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2015 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
YL-30	2015	23-May	ANG-7	WALL	367	475	0.961	Male	1	4	0.172
YL-31	2015	23-May	ANG-7	WALL	346	425	1.026	Male	1	4	0.310
YL-32	2015	23-May	ANG-7	WALL	362	550	1.159	Female	0	5	0.246
YL-33	2015	23-May	ANG-6	NRPK	665	1850	0.629	Male	1	5	0.725
YL-34	2015	24-May	HP-2	WALL	358	500	1.090	Male	1	4	0.200
YL-35	2015	24-May	HP-2	WALL	410	800	1.161	Female	1	7	0.315
YL-36	2015	24-May	HP-2	WALL	422	900	1.198	Male	1	7	0.480
YL-38	2015	24-May	HP-1	NRPK	421	500	0.670	Male	1	4	0.134
YL-39	2015	24-May	ANG-7	WALL	378	550	1.018	Male	1	8	0.330
YL-40	2015	24-May	ANG-7	WALL	433	850	1.047	Male	1	10	0.619
YL-41	2015	24-May	ANG-7	WALL	331	300	0.827	Male	1	6	0.335
YL-42	2015	24-May	ANG-7	WALL	327	425	1.215	Male	0	5	0.223
YL-43	2015	24-May	ANG-6	NRPK	468	650	0.634	Male	1	4	0.357
YL-47	2015	24-May	ANG-5	NRPK	502	900	0.711	Female	1	5	0.409
YL-48	2015	24-May	ANG-5	NRPK	505	925	0.718	Female	1	6	0.408
YL-50	2015	24-May	ANG-5	NRPK	607	1325	0.592	Male	1	6	0.625
YL-51	2015	24-May	ANG-5	NRPK	656	1800	0.638	Male	1	7	0.850
YL-52	2015	24-May	ANG-5	NRPK	625	1450	0.594	Female	N/A	6	0.537
YL-53	2015	24-May	GN-8	WALL	461	1050	1.072	Female	1	7	0.263
YL-54	2015	24-May	GN-8	NRPK	472	775	0.737	Male	1	6	0.375
YL-55	2015	25-May	GN-9	WALL	462	1100	1.115	Female	0	6	0.218
YL-56	2015	25-May	GN-9	WALL	486	1150	1.002	Female	1	6	0.318
YL-57	2015	25-May	GN-9	WALL	434	800	0.979	Male	1	7	0.272
YL-58	2015	25-May	GN-9	NRPK	695	2150	0.640	Female	1	7	0.790
YL-59	2015	25-May	GN-10	WALL	402	700	1.078	Male	1	6	0.238
YL-60	2015	25-May	GN-10	WALL	374	525	1.004	Male	1	5	0.225

Table A1-2. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at York Landing in 2015 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
YL-61	2015	25-May	GN-10	WALL	384	675	1.192	Male	1	6	0.190
YL-62	2015	25-May	GN-9	WALL	392	600	0.996	Male	1	6	0.253
YL-63	2015	25-May	GN-9	WALL	427	850	1.092	Female	1	6	0.229
YL-64	2015	25-May	GN-9	WALL	485	1100	0.964	Female	1	6	0.199
YL-65	2015	25-May	GN-9	WALL	401	575	0.892	Male	1	7	0.344
YL-66	2015	25-May	GN-9	WALL	395	650	1.055	Female	0	6	0.250
YL-67	2015	25-May	GN-9	WALL	400	600	0.938	Female	0	6	0.242
YL-69	2015	25-May	GN-9	NRPK	556	1250	0.727	Female	1	6	0.399
YL-70	2015	25-May	GN-10	WALL	401	700	1.086	Female	0	6	0.236
YL-71	2015	25-May	GN-10	WALL	443	925	1.064	Female	1	7	0.288
YL-72	2015	25-May	GN-10	WALL	478	1025	0.939	Female	1	6	0.249
YL-73	2015	25-May	GN-10	WALL	483	1300	1.154	Female	1	6	0.210
YL-74	2015	25-May	GN-10	NRPK	541	1000	0.632	Female	1	6	0.515
YL-76	2015	25-May	GN-9	WALL	393	625	1.030	Female	0	6	0.232
YL-77	2015	25-May	GN-9	WALL	523	1450	1.014	Female	1	7	0.569
YL-78	2015	25-May	GN-9	WALL	391	675	1.129	Female	0	6	0.244
YL-79	2015	25-May	GN-9	WALL	456	1000	1.055	Female	1	6	0.291
YL-80	2015	25-May	GN-9	NRPK	576	1500	0.785	Male	1	5	0.313
YL-81	2015	25-May	GN-10	WALL	443	925	1.064	Female	1	7	0.231
YL-82	2015	25-May	GN-10	WALL	424	800	1.050	Female	0	7	0.226
YL-83	2015	25-May	GN-10	WALL	419	850	1.156	Male	1	6	0.246

Table A1-3. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2015.

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
IF-01	2015	20-May	ANG-1	WALL	366	500	1.020	Male	1	6	0.334
IF-02	2015	20-May	ANG-1	WALL	367	500	1.012	Male	1	6	0.269
IF-03	2015	20-May	ANG-1	WALL	433	850	1.047	Male	1	8	0.311
IF-04	2015	20-May	ANG-1	WALL	371	600	1.175	Male	1	6	0.285
IF-05	2015	20-May	ANG-1	WALL	356	500	1.108	Male	1	6	0.211
IF-06	2015	20-May	ANG-1	WALL	358	500	1.090	Male	1	6	0.358
IF-07	2015	20-May	ANG-1	NRPK	509	900	0.682	Male	1	5	0.204
IF-08	2015	20-May	ANG-1	WALL	370	500	0.987	Male	1	6	0.316
IF-09	2015	20-May	ANG-1	WALL	420	800	1.080	Male	1	7	0.322
IF-10	2015	20-May	ANG-1	WALL	382	650	1.166	Male	1	7	0.266
IF-11	2015	20-May	ANG-1	WALL	404	750	1.137	Female	1	6	0.241
IF-12	2015	20-May	ANG-1	WALL	413	700	0.994	Female	0	7	0.325
IF-13	2015	20-May	ANG-1	WALL	359	500	1.081	Male	1	5	0.285
IF-14	2015	20-May	ANG-1	WALL	367	500	1.012	Male	1	5	0.292
IF-15	2015	20-May	ANG-1	NRPK	502	800	0.632	Female	1	5	0.631
IF-16	2015	20-May	ANG-2	NRPK	513	900	0.667	Female	1	5	0.616
IF-17	2015	20-May	ANG-2	NRPK	589	1400	0.685	Female	1	6	0.336
IF-18	2015	20-May	ANG-2	NRPK	535	1000	0.653	Female	1	5	0.468
IF-19	2015	20-May	ANG-1	NRPK	494	950	0.788	Female	1	4	0.419
IF-20	2015	20-May	ANG-1	NRPK	438	600	0.714	Female	0	4	0.100
IF-21	2015	20-May	ANG-1	NRPK	455	650	0.690	Female	0	5	0.179
IF-22	2015	20-May	ANG-1	WALL	385	600	1.051	Male	1	6	0.286
IF-23	2015	20-May	ANG-1	WALL	411	800	1.152	Female	1	6	0.254
IF-24	2015	20-May	ANG-1	WALL	453	900	0.968	Female	1	6	0.269
IF-25	2015	20-May	GN-2	WALL	477	1300	1.198	Female	1	6	0.231

Table A1-3. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2015 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
IF-26	2015	20-May	GN-2	WALL	444	1150	1.314	Female	1	8	0.310
IF-27	2015	20-May	GN-2	NRPK	505	850	0.660	Female	1	5	0.207
IF-28	2015	20-May	GN-2	NRPK	515	1050	0.769	Female	1	6	0.095
IF-29	2015	20-May	GN-2	NRPK	500	1100	0.880	Female	1	6	0.285
IF-30	2015	20-May	GN-2	NRPK	496	900	0.738	Female	1	5	0.083
IF-31	2015	21-May	ANG-1	NRPK	504	800	0.625	Female	1	5	0.398
IF-32	2015	21-May	ANG-1	NRPK	475	800	0.746	Male	1	5	0.233
IF-33	2015	21-May	ANG-1	WALL	417	750	1.034	Male	1	6	0.254
IF-34	2015	21-May	GN-2	NRPK	613	1550	0.673	Female	1	6	0.526
IF-35	2015	21-May	ANG-1	NRPK	415	550	0.770	Female	0	4	0.155
IF-36	2015	21-May	ANG-2	NRPK	515	875	0.641	Female	1	5	0.380
IF-37	2015	21-May	ANG-2	NRPK	528	1050	0.713	Female	1	6	0.147
IF-38	2015	21-May	GN-2	NRPK	577	1600	0.833	Female	1	6	0.185
IF-39	2015	21-May	GN-2	NRPK	510	1050	0.792	Female	1	5	0.208
IF-40	2015	21-May	ANG-1	WALL	422	750	0.998	Male	1	6	0.414
IF-41	2015	21-May	ANG-1	WALL	406	700	1.046	Female	1	7	0.321
IF-43	2015	21-May	SN-1	WALL	342	425	1.062	Male	1	6	0.259
IF-44	2015	21-May	GN-2	NRPK	545	1050	0.649	Female	1	6	0.781
IF-45	2015	21-May	GN-2	NRPK	651	1675	0.607	Male	1	7	0.780
IF-46	2015	21-May	GN-2	NRPK	623	1600	0.662	Female	1	6	0.181
IF-48	2015	21-May	ANG-2	WALL	420	725	0.979	Male	1	6	0.365
IF-49	2015	21-May	ANG-1	WALL	371	500	0.979	Male	1	6	0.323
IF-50	2015	21-May	ANG-1	NRPK	495	750	0.618	Female	1	4	0.241
IF-51	2015	21-May	ANG-1	NRPK	435	575	0.699	Female	0	4	0.169
IF-52	2015	21-May	ANG-1	WALL	421	825	1.106	Male	1	7	0.263
IF-53	2015	21-May	ANG-1	WALL	463	1200	1.209	Male	1	8	0.338

Table A1-3. Muscle mercury (Hg) concentrations and other biological data for Northern Pike and Walleye from the Aiken River at Ilford in 2015 (continued).

Fish #	Year	Date	Site	Species	Length (mm)	Weight (g)	K	Sex	Mat	Age (yr)	Hg (ppm)
IF-54	2015	21-May	ANG-1	WALL	354	450	1.014	Male	1	5	0.223
IF-55	2015	21-May	ANG-1	WALL	397	625	0.999	Male	1	7	0.306
IF-56	2015	21-May	ANG-1	WALL	406	675	1.009	Male	1	8	0.470
IF-57	2015	21-May	ANG-2	WALL	432	850	1.054	Male	1	6	0.338
IF-58	2015	21-May	ANG-1	NRPK	533	975	0.644	Male	1	6	0.568
IF-59	2015	21-May	ANG-1	NRPK	558	1100	0.633	Male	1	6	0.282
IF-60	2015	21-May	ANG-1	NRPK	506	850	0.656	Female	1	5	0.365
IF-61	2015	21-May	ANG-2	NRPK	527	900	0.615	Female	1	5	0.446
IF-62	2015	21-May	ANG-2	NRPK	447	600	0.672	Female	1	4	0.266
IF-63	2015	21-May	ANG-2	NRPK	410	450	0.653	Male	1	4	0.220
IF-64	2015	21-May	ANG-2	NRPK	522	1125	0.791	Female	1	5	0.298
IF-65	2015	21-May	ANG-2	NRPK	538	1075	0.690	Female	1	6	0.550
IF-66	2015	21-May	GN-2	NRPK	652	1800	0.649	Male	1	6	0.612
IF-67	2015	21-May	ANG-2	WALL	452	925	1.002	Female	1	7	0.319
IF-68	2015	22-May	ANG-2	NRPK	483	775	0.688	Male	1	6	0.328
IF-69	2015	22-May	ANG-2	WALL	428	800	1.020	Male	1	6	0.305
IF-70	2015	22-May	ANG-2	WALL	370	600	1.185	Male	1	6	0.253
IF-71	2015	22-May	ANG-2	WALL	385	625	1.095	Male	1	6	0.251
IF-72	2015	22-May	ANG-2	WALL	368	575	1.154	Male	1	6	0.275
IF-73	2015	22-May	ANG-2	WALL	357	550	1.209	Male	1	6	0.204
IF-74	2015	22-May	ANG-2	WALL	459	1050	1.086	Male	1	8	0.717
IF-75	2015	22-May	GN-2	NRPK	660	1725	0.600	Female	1	7	0.700

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