Predictions of Peak Fish Mercury Concentrations Associated with the Kapuskasing River Hydroelectric Project

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1 Introduction

Fish mercury concentrations have been well documented to increase in connection with flooding in new reservoirs, although data are very limited for small hydroelectric developments. Increased mercury levels in fish are a concern because most of the mercury in fish is methylmercury (MeHg), a toxic form that occurs naturally but can represent a health risk if overexposure occurs (Mergler *et al.*, 2007.) The response of fish mercury concentrations following flooding is affected by reservoir-specific features including the percent of the reservoir consisting of newly flooded terrain, the type of flooded terrain, the hydraulic residence time, and erosion. Greater increases in fish mercury are expected as the percent of the reservoir that is flooded terrain increases. On the other hand, short hydraulic residence times should result in lower MeHg concentrations in surface waters of reservoirs via dilution and in fish (depending on the food web structure), but create the potential for greater downstream transport.

Xeneca Power Development Inc. (Xeneca) is proposing to construct and operate three hydroelectric generating stations on the Kapuskasing River. Given that flooding is associated with the proposed projects, the potential exists for fish Hg concentrations to increase in the new reservoirs. This report describes an assessment of potential increases in fish mercury concentrations in the proposed headponds.

2 Project Description

The three proposed generating stations (upstream to downstream) are Buchan Falls GS, Clouston Rapids GS and Cedar Rapids with installed capacities of 9.99 MW, 5 MW and 3.75 MW respectively (Hatch, 2014.) The sites are also referred to as Lapinigam, Middle Township Buchanan and Near North Boundary in some project documentation (Hatch, 2014.) The project sites are located on the Kapuskasing River approximately 100 km south of the Town of Kapuskasing, Ontario (Figure 1) in the Townships of Buchan, Clouston, Allenby and Maude in the District of Algoma (Hatch, 2014.)

The Buchan Falls GS at Lapinigam Rapids will operate as a normal or modified run-of-river facility depending on flow conditions (Hatch, 2014.) The headpond will have a newly flooded area of 99 ha and a total headpond area of 135 ha. Seventy-three percent of the headpond area will be newly flooded terrain. Flooded wetlands will represent 36% of the headpond area and 49% of the newly flooded area. The mean annual flow is37.3 $m^3 s^{-1}$ and the mean hydraulic residence time in the proposed headpond is 24 hours (Xeneca, 2014.)

The Clouston Rapids GS at Middle Township Buchan will operate as a run-of-river as well as a cascading or partially cascading facility depending on flow conditions and final decisions regarding operating options (Hatch, 2014.) The headpond will have a newly flooded area of 20 ha and a total headpond area of 67 ha. Thirty percent of the headpond area will be newly flooded terrain. No newly flooded terrain will be wetland. The mean annual flow is 37.5 $m^3 s^{-1}$ and the mean hydraulic residence time in the proposed headpond is 7.5 hours (Xeneca, 2014.)

The Cedar Rapids GS at Near North Boundary will also operate as a run-of-river and either a cascading or partially cascading facility (Hatch, 2014.) The headpond will have a newly flooded area of 27 ha and a total headpond area of 78 ha. Thirty-five percent of the headpond area will be newly flooded terrain. Flooded wetlands will represent approximately 12% of the headpond area and 33% of the newly flooded area. The mean annual flow is 45.1 $m^3 s^{-1}$ and the mean hydraulic residence time in the proposed headpond is 4.4 hours (Xeneca, 2014.)

The operating plans for the proposed generating stations allow for a limited amount of fluctuation in headpond water levels. Xeneca has proposed a maximum daily water level fluctuation of 1.0 m in the three proposed headponds (Hatch, 2014.)Due to the short water residence times in the headponds, thermal stratification is not expected to occur. Surface water temperatures may increase over existing conditions; however, no shift in the thermal regime is anticipated (Hatch, 2014.) There are no existing impoundments upstream of the three project sites on the Kapuskasing River.

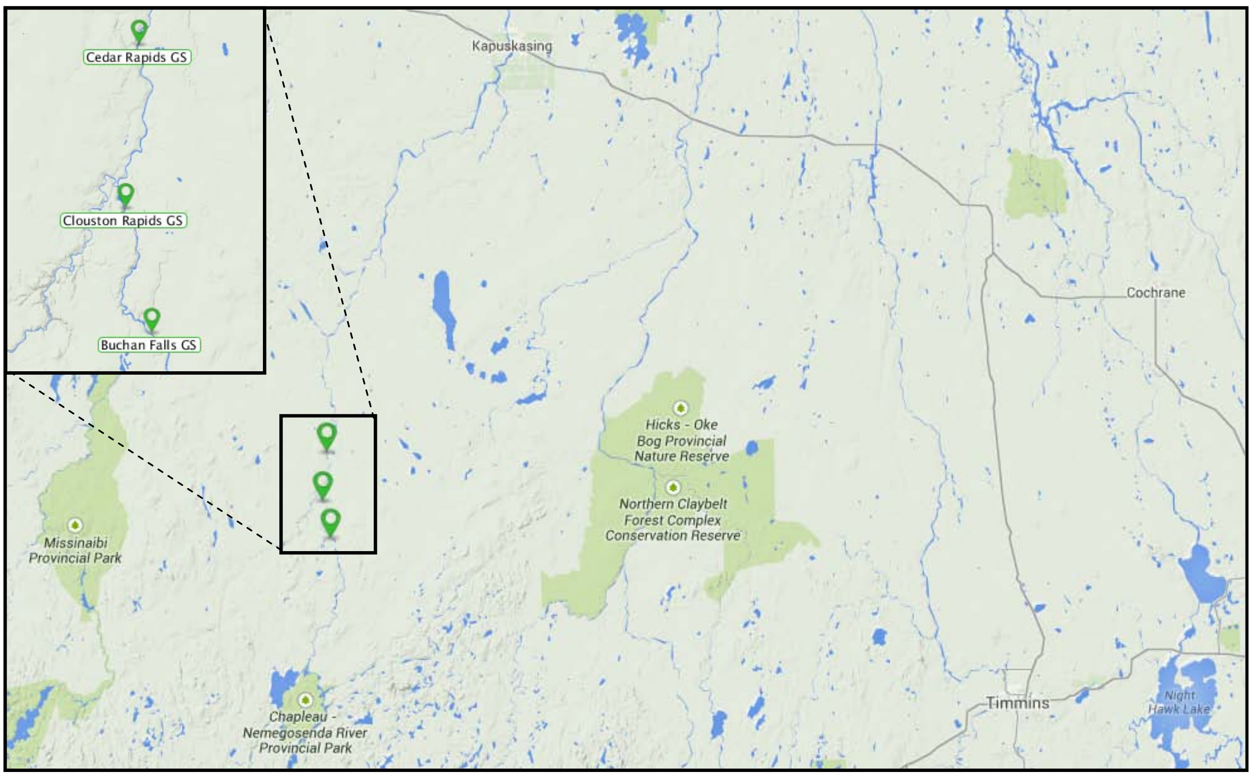

Figure 1. Map showing the three proposed generating stations comprising the Kapuskasing River Hydroelectric Project.

3 Study Approach

Several simple regression models have been developed to predict peak fish mercury concentrations in new reservoirs. These models can be grouped into two basic types. The first group directly predicts mercury concentrations in fish based on reservoir conditions. Pre-flood mercury levels are not directly used as model inputs. Examples include Bodaly *et al.* (2007), who predicted peak concentrations using the ratio of flooded area to original area, and Johnston *et al.* (1991) who predicted the mass (burden) of mercury in fish based onsite conditions such as the ratio of flooded area to total area. These burdens can be converted to concentrations by dividing by the weight of a fish of standard length.

Harris *et al.* also recently developed a model that predicts peak fish mercury concentrations directly on the basis of the flooded area, total area, and water flow rate. Predictions from this model for walleye are not presented because the model appears to underpredict peak concentrations for small hydro sites based on limited available data (Harris and Beals, 2014.) Additional data for small hydro sites are needed to improve the predictive capabilities of the Harris *et al.* peak concentration model for walleye.

A second general approach predicts the relative increase in fish mercury concentration (*e.g.*3×) and then multiplies this value by baseline fish mercury concentration to predict the peak concentration (*e.g.* Harris and Beals, 2014a, b; Harris *et al.*, 2011.) It is also possible to use the Johnston *et al.* and Bodaly *et al.* models to predict relative increases, although the original publications did not use these models in this manner. Peak predicted Hg concentrations or burdens can be divided by the model predictions if no flooding occurs (*i.e.* the model intercept) to predict a relative increase. The relative increase can then be multiplied by the baseline concentration for the proposed site.

The extent to which pre-flood mercury concentrations in fish affect post-flood peak concentrations, and therefore which of the two modeling approaches is better, is not clear. These approaches may produce similar results if the baseline concentration at a proposed project site is similar to values predicted by the models if no flooding occurs. For example, the baseline concentration (model intercept) for 40 cm walleye from the Bodaly *et al.* model is 0.50 µg g^{-1}.This is significantly lower than the walleye baseline the project sites (0.89 µg g^{-1}.) In this case, assumptions about the influence of pre-flood mercury concentrations likely affect peak predicted values.

Six models were used to predict peak mercury concentrations:

1) <u>Johnston *et al.* (1991) percent flooding (PF) model</u>

   Peak Hg = Burden / W

   where:

Peak Hg	= maximum post-flood Hg concentration ($\mu g\ g^{-1}$ muscle)
W	= fish weight (g)
Burden	= Hg mass in fish (μg)
	= (10.18 × PF) + 292.7for 40 cm walleye
	= (15.70 × PF) + 565.0 for 55 cm northern pike
PF	= 100 × flooded area/total area

   The burden is estimated from existing reservoirs by multiplying the Hg concentration in muscle by the weight of the fish. The predicted concentrations are therefore equivalent to muscle concentrations.

2) <u>Bodaly *et al.* (2007) model</u>

   Peak Hg = $y_o + a\,(1 - e^{-bx})$

   Where :

Peak Hg	= maximum post-flood Hg concentration ($\mu g\ g^{-1}$ muscle)
x	= flooded area/original area × 100

   For 40 cm walleye:

y_o	= 0.501
a	= 1.137
b	= 0.024

   For 55 cm northern pike:

y_o	= 0.450
a	= 1.127
b	= 0.034

3) Harris *et al.* peak increase factor (PIF)model

Peak Hg = PIF × Baseline Hg

Where:

Peak Hg	= maximum post-flood Hg concentration (µg g^{-1} muscle)
Baseline Hg	= pre-flood Hg concentration (µg g^{-1} muscle)
PIF	= peak fish Hg/Baseline fish Hg
	$= k_1 \times \frac{A_f}{(Q + k_2 \times A_t)} + k_3$
A_f	= flooded area (km^2)
A_t	= total reservoir area (km^2)
Q	= mean annual flow ($km^3 yr^{-1}$)
k_1	= regression coefficients ($kmyr^{-1}$)
k_2	= regression coefficients ($kmyr^{-1}$)
k_3	= regression coefficients (dimensionless)

For 40 cm walleye:

$k_1 = 8.62 \times 10^{-2}$
$k_2 = 2.54 \times 10^{-4}$
$k_3 = 1.51$

For 55 cm northern pike:

$k_1 = 0.635$
$k_2 = 8.34 \times 10^{-2}$
$k_3 = 1.33$

4) Harris *et al.* model to directly predict mercury concentrations in northern pike

Peak Hg = $= 0.215 \times \frac{A_f}{(Q + 0.084 \times A_t)} + 0.55$

Where:

Peak Hg	= maximum post-flood Hg concentration (µg g^{-1} muscle)
A_f	= flooded area (km^2)
A_t	= total reservoir area (km^2)
Q	= mean annual flow ($km^3 yr^{-1}$)

5) Johnston *et al.* (1991) model used to predict relative increase

Peak Hg = PIF × Baseline Hg

Where:

Peak Hg	= maximum post-flood Hg concentration (µg g^{-1} muscle)
Baseline Hg	= pre-flood Hg concentration (µg g^{-1} muscle)
PIF	= peak Hg burden from Johnston model /Johnston model intercept

This approach was used for smallmouth bass because Johnston et al. (1991) did not publish a version of the model specifically for smallmouth bass.

6) Bodaly *et al.* (2007) model used to predict relative increase

Peak Hg = PIF × Baseline Hg

Where:

Peak Hg	= maximum post-flood Hg concentration (µg g^{-1} muscle)
Baseline Hg	= pre-flood Hg concentration (µg g^{-1} muscle)
PIF	= peak Hg concentration from Bodaly model /Bodaly model intercept

This approach was used for smallmouth bass because Johnston et al. (1991) did not publish a version of the model specifically for smallmouth bass.

Because of the uncertainties associated with the above models, all were applied to provide a range of estimates of peak fish mercury concentrations. Predictions were made for 40 cm walleye, 55 cm northern pike and 35 cm smallmouth bass in the proposed Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS headponds.

For walleye and northern pike, all models were applied in the manner in which they were originally published. The Johnston *et al.* and Bodaly *et al.* models were only used to directly predict concentrations and not to predict relative increases, which were predicted with the Harris *et al.* PIF model. The relative increase predicted for northern pike was also applied to walleye, under the assumption that these species would increase similarly in relative terms. This additional estimate for walleye was motivated by the fact that the Harris *et al.* PIF model for northern pike was derived from a larger dataset than the walleye model (n = 12 versus n = 7.) A higher level of confidence is associated with its predictions, although both models are statistically significant at the $p<0.01$ level.

Unfortunately, none of these models have been developed for smallmouth bass. Because fish mercury concentrations differ among species, it was not possible to use the burden or concentration-based models for one species to directly make predictions for another. However, it was possible to use these models to predict the relative increases expected, and then multiply these values by baseline concentrations for smallmouth bass to predict peak concentrations.

Models developed for walleye and northern pike were used to predict relative increases in smallmouth bass, as these species all occupy higher trophic levels in food webs.

Another modeling approach is to use the slope of the Johnston *et al.* PF equation, but not the published intercept. The intercept represents the model-predicted concentration with no flooding for the model building dataset from Manitoba. The intercept can be adjusted to match the site specific baseline concentration for the proposed project. Our view of this approach is that the slope and intercept of the Johnston *et al.* equation are a paired set of coefficients that best fit the model building dataset. It is not advisable to change one coefficient in isolation, as the resulting equation (slope and intercept) would no longer provide an optimal fit to any dataset. It would be preferable to refit the linear regression using a forced intercept (equal to the project baseline), or to use approach #4 above. The latter was done for this study.

4 Baseline Fish Mercury Concentrations at the Project Site

Fish were sampled at four locations in the Kapuskasing River between April 21 and May 2, 2010 (Hatch, 2014): Kapuskasing Lake Outlet, Clouston Rapids, Cedar Rapids and a Downstream Control site. Fish tissue samples were analyzed for total mercury by Flett Research Ltd.

Less than ten fish mercury samples were available at the Clouston Rapids GS and Cedar Rapids GS sites for walleye, northern pike and smallmouth bass. There were no samples in the immediate vicinity of Buchan Falls GS. Individual data sets for each site were considered to be too limited to derive reliable baseline mercury-length and weight-length relationships via regression analysis. Instead, baseline conditions were determined by combining all available data in the Kapuskasing River study area for each fish species, excluding the Kapuskasing Lake Outlet samples. This approach is considered reasonable since fish can migrate from the Downstream Control location to Buchan Falls, but not beyond that point to the outlet of Kapuskasing Lake (Trion Clarke, personal communication, May 29, 2014.)

Length, weight and mercury concentration data were available for 21 walleye (Table 1, Figure 2.) The estimated mercury concentration for a 400 mm walleye was 0.89 µg g^{-1} using the equation shown in Figure 2. Walleye weight versus length is plotted in Figure 3. A 400 mm walleye weighs 489 g based on the equation shown in Figure 5. This information is needed to convert mercury body burdens predicted by the Johnston *et al.* (1991) model into concentrations.

Table 1.Walleye data for the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

Total Length (mm)	**Total Weight** (wet g)	**Total Hg** (µg g^{-1} wet wt.)	**Sample location**
401	630	0.49	Clouston Rapids
384	380	0.56	Clouston Rapids
408	640	0.56	Clouston Rapids
375	240	0.63	Clouston Rapids
335	220	0.69	Clouston Rapids
341	180	0.97	Clouston Rapids
358	280	1.03	Clouston Rapids
549	1330	1.58	Clouston Rapids
361	420	0.39	Cedar Rapids
439	240	0.56	Cedar Rapids
340	320	0.62	Cedar Rapids
357	400	0.75	Cedar Rapids
326	250	0.85	Cedar Rapids
449	790	1.43	Cedar Rapids
406	550	1.56	Cedar Rapids
525	1620	1.81	Cedar Rapids
321	290	0.56	Downstream of Cedar Rapids
442	770	1.03	Downstream of Cedar Rapids
393	480	1.14	Downstream of Cedar Rapids
316	200	1.26	Downstream of Cedar Rapids
606	2050	1.60	Downstream of Cedar Rapids

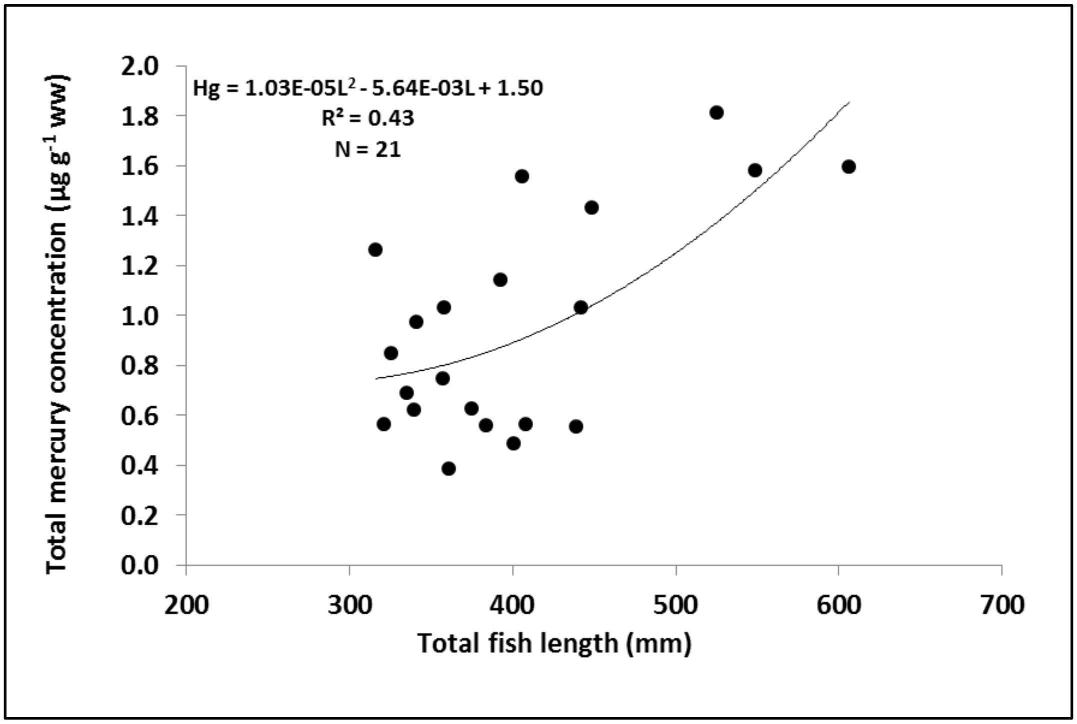

Figure 2. Fish mercury concentrations versus total length for walleye sampled near the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

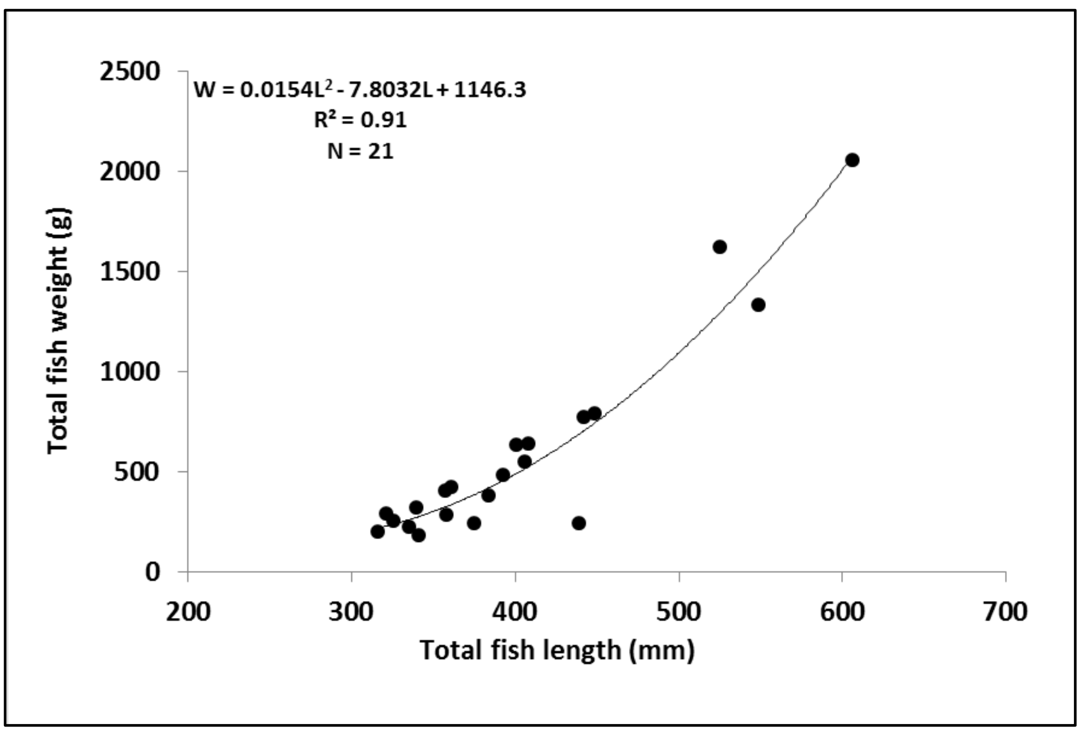

Figure 3.Fish weight versus total length for walleye sampled near the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

Length, weight and mercury concentration data were available for 24northern pike collected in the Kapuskasing River (Table 2, Figure 4.) As previously discussed, samples from the outlet of Kapuskasing Lake were not included, leaving 17 samples used for the regression analysis. The estimated mercury concentration for a 550 mm northern pike was 0.60 µg g^{-1} using the equation shown in Figure 4.Northern pike weight versus length is plotted in Figure 5. A 550 mm northern pike weighs 878 g based on the equation shown in Figure 5.

Table 2.Northern pike data for the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Samples from Kapuskasing Lake Outlet were not included in the regression analysis. Data from Hatch (2011.)

Total Length (mm)	**Total Weight** (wet g)	**Total Hg** (µg g^{-1} wet wt.)	**Sample location**
490	700	0.64	Kapuskasing Lake Outlet
540	980	0.65	Kapuskasing Lake Outlet
483	730	0.67	Kapuskasing Lake Outlet
607	1300	0.68	Kapuskasing Lake Outlet
620	1430	0.69	Kapuskasing Lake Outlet
585	1150	0.83	Kapuskasing Lake Outlet
730	2080	1.57	Kapuskasing Lake Outlet
585	1450	0.66	Clouston Rapids
740	2690	0.69	Clouston Rapids
625	1550	1.06	Clouston Rapids
456	590	0.50	Cedar Rapids
542	820	0.82	Cedar Rapids
638	1480	0.88	Cedar Rapids
445	530	0.35	Downstream of Cedar Rapids
375	370	0.40	Downstream of Cedar Rapids
662	1330	0.40	Downstream of Cedar Rapids
465	300	0.53	Downstream of Cedar Rapids
448	670	0.60	Downstream of Cedar Rapids
621	1430	0.70	Downstream of Cedar Rapids
780	3680	0.74	Downstream of Cedar Rapids
495	730	1.02	Downstream of Cedar Rapids
434	400	0.31	Downstream of Cedar Rapids
579	810	0.68	Downstream of Cedar Rapids
880	4760	1.89	Downstream of Cedar Rapids

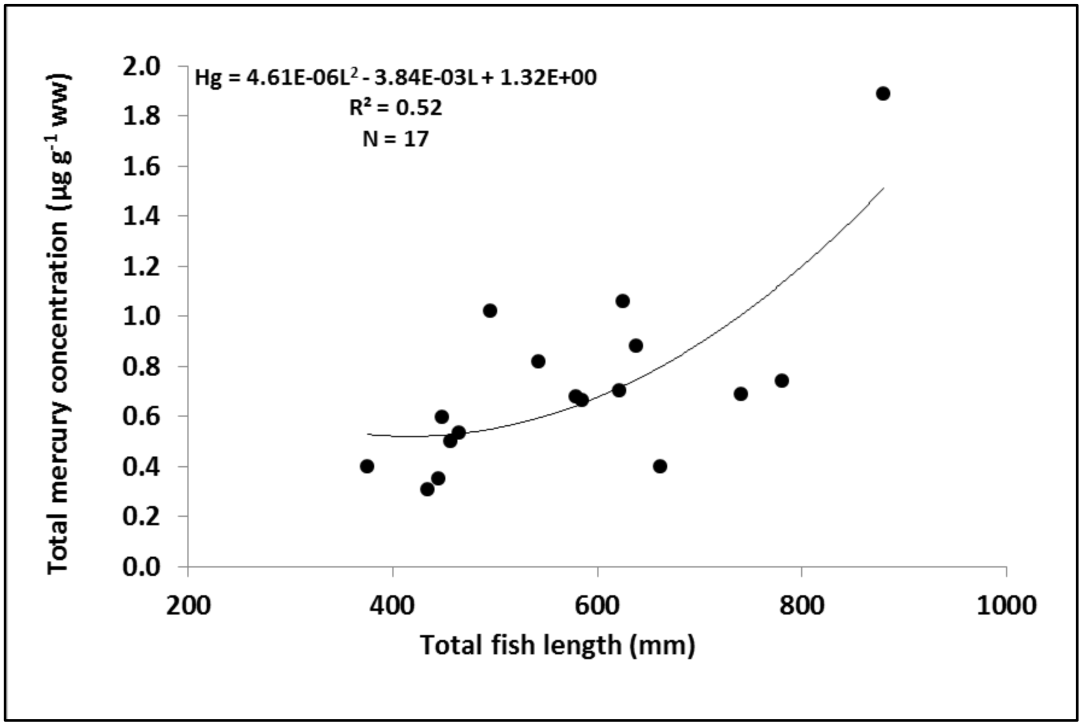

Figure 4. Fish mercury concentrations versus total length for northern pike sampled near the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring2010. Data from Hatch (2011.)

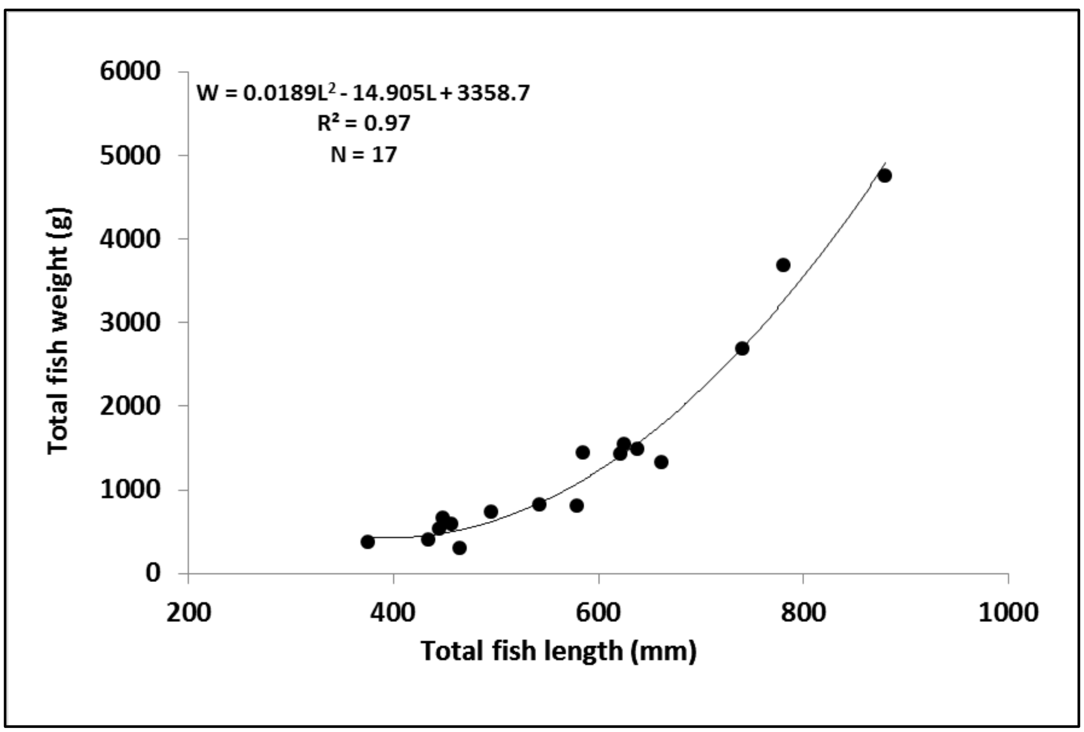

Figure 5. Fish weight versus total length for northern pike sampled near The proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

Length, weight and mercury concentration data were available for 19 smallmouth bass collected in the Kapuskasing River (Table 3, Figure 6.) The estimated mercury concentration for a 350 mm smallmouth bass was 0.51 µg g^{-1} using the equation shown in Figure 6. Based on the weight versus length data plotted in Figure 7, a 350 mm smallmouth bass weighs 662 g.

Table 3.Smallmouth bass data for the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

Total Length (mm)	**Total Weight** (wet g)	**Total Hg** (µg g^{-1} wet wt.)	**Sample location**
331	590	0.39	Clouston Rapids
395	1100	0.44	Clouston Rapids
349	630	0.46	Clouston Rapids
405	1070	0.55	Clouston Rapids
365	690	0.65	Clouston Rapids
391	870	0.68	Clouston Rapids
435	1160	0.72	Clouston Rapids
387	960	0.74	Clouston Rapids
383	780	0.76	Clouston Rapids
334	640	0.43	Cedar Rapids
380	850	0.60	Cedar Rapids
376	660	0.60	Cedar Rapids
388	1020	0.70	Cedar Rapids
310	400	0.32	Downstream of Cedar Rapids
340	570	0.34	Downstream of Cedar Rapids
298	900	0.66	Downstream of Cedar Rapids
397	1010	0.69	Downstream of Cedar Rapids
299	460	0.35	Downstream of Cedar Rapids
328	500	0.38	Downstream of Cedar Rapids

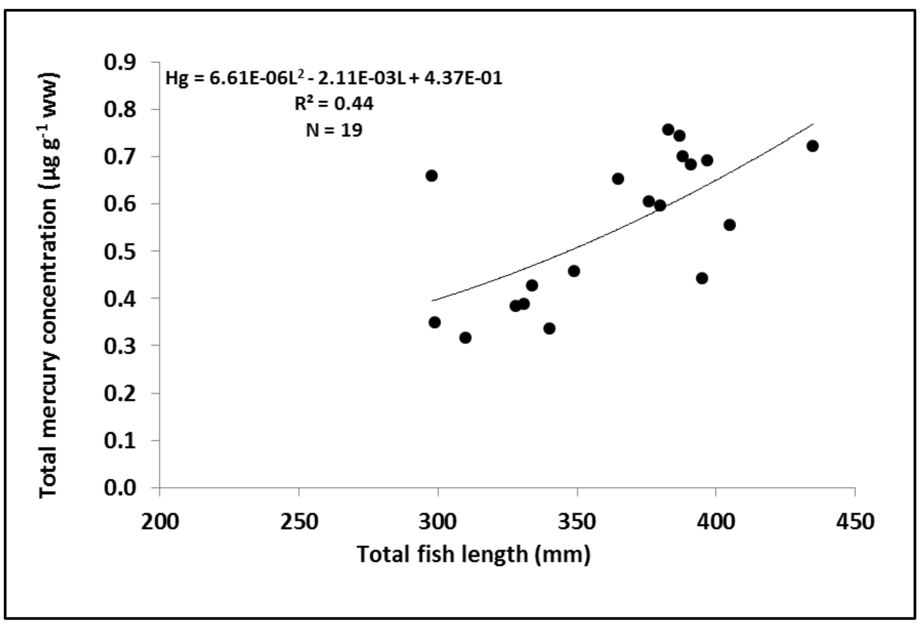

Figure 6. Fish mercury concentrations versus total length for smallmouth bass sampled near the proposed Kapuskasing River Hydroelectric Project.
Sampling was carried out in spring 2010. Data from Hatch (2011.)

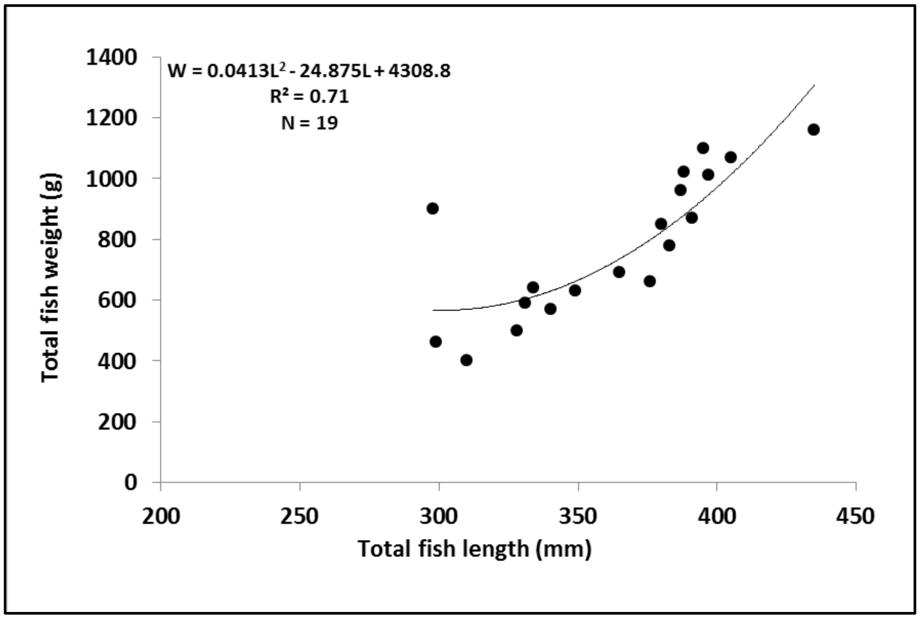

Figure 7. Fish weight versus total length for smallmouth bass sampled near the proposed Kapuskasing River Hydroelectric Project. Sampling was carried out in spring 2010. Data from Hatch (2011.)

5 Predicted Peak Fish Mercury Concentrations

Predicted peak mercury concentrations for 40 cm walleye, 55 cm northern pike and 35 cm smallmouth bass in the proposed Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS headponds are shown in Tables 4 - 6.

Results based on models that directly predict peak concentrations or burdens in walleye or northern pike are given in Table 4. As previously discussed, no models directly predicting concentrations were available for smallmouth bass. Results for walleye, northern pike and smallmouth bass that were estimated using models predicting peak relative increases are given in Table 5. Overall, concentrations predicted in 40 cm walleye ranged from 1.2 to 2.1µg g^{-1} in the three headponds, increasing from a baseline of 0.89 µg g^{-1}. Predictions for 55 cm northern pike ranged from 0.7 to 2.0 µg g^{-1}, increasing from a baseline of 0.60 µg g^{-1}. Predictions for 35 cm smallmouth bass ranged from 0.8 to 1.8 µg g^{-1}, increasing from a baseline of 0.51 µg g^{-1}. No single model consistently predicted the highest or lowest concentrations across all sites and species, although models that considered flow often predicted lower peak values. For example, the Harris *et al.* model directly predicting concentrations in northern pike produced the lowest estimates for that species in all three headponds. An exception to this tendency was that the Harris *et al.* relative increase model for pike produced the highest values in Clouston Rapids and Cedar Rapids headponds when those relative increases were applied to walleye.

Table 4. Predicted peak mercury concentrations and relative increases predicted for 40 cm walleye and 55 cm northern pike in the proposed Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS headponds based on models that directly predict concentrations or burdens. Predicted peak concentrations from these models are independent of the Kapuskasing River baseline concentrations.

Model used to predict peak concentration or burden	Buchan Falls GS		Clouston Rapids GS		Cedar Rapids GS	
	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)
Walleye, 40 cm						
Johnston *et al.* (1991) PF	2.4	2.1	1.4	1.2	1.5	1.3
Bodaly *et al.* (2007)	1.8	1.6	1.4	1.2	1.5	1.3
Northern pike, 55 cm						
Johnston *et al.* (1991) PF	3.2	2.0	2.0	1.2	2.1	1.3
Bodaly *et al.* (2007)	2.6	1.6	2.2	1.3	2.3	1.4
Harris *et al.*	1.2	0.7	1.2	0.7	1.2	0.7

Table 5. Predicted peak mercury concentrations and relative increases for 40 cm walleye, 55 cm northern pike and 35 cm smallmouth bass in the proposed Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS headponds based on predictions of peak increase factors. Peak increase factors were multiplied by the Kapuskasing River baseline concentrations to predict peak concentrations.

Model used to predict PIF	Buchan Falls GS		Clouston Rapids GS		Cedar Rapids GS	
	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)	Predicted peak/baseline ratio	Predicted peak concentration (µg g^{-1} wet muscle)
Walleye, 40 cm						
Harris *et al.* - PIF walleye	1.6	1.4	1.6	1.4	1.6	1.4
Harris *et al.* - PIF n. pike	1.8	1.6	1.9	1.7	1.9	1.7
Northern pike, 55 cm						
Harris *et al.* - PIF n. pike	1.8	1.1	1.9	1.1	1.9	1.1
Smallmouth bass, 35 cm						
Johnston *et al.* (1991) PF walleye	3.6	1.8	2.0	1.0	2.2	1.1
Johnston *et al.* (1991) PF n. pike	3.0	1.5	1.8	0.9	2.0	1.0
Bodaly *et al.* (2007) walleye	3.3	1.7	2.5	1.2	2.6	1.3
Bodaly *et al.* (2007) n. pike	3.5	1.8	2.9	1.5	3.1	1.6
Harris *et al.* - PIF walleye	1.6	0.8	1.6	0.8	1.6	0.8
Harris *et al.* - PIF n. pike	1.8	0.9	1.9	1.0	1.9	1.0

Table 6. Ranges of predicted fish mercury concentrations by species and headpond

Fish Species	Baseline concentration ($\mu g g^{-1}$ wet muscle)	Predicted peak mercury concentration in headpond ($\mu g\ g^{-1}$ wet muscle)		
		Buchan Falls	Clouston Rapids	Cedar Rapids
Walleye (40 cm)	0.89	1.4 – 2.1	1.2 – 1.7	1.3 – 1.7
Northern Pike (55 cm)	0.60	0.7 – 2.0	0.7 – 1.3	0.7 – 1.4
Smallmouth Bass (35 cm)	0.51	0.8 – 1.8	0.8 – 1.5	0.8 – 1.6

In order to demonstrate the confidence associated with predictions, results from the Harris *et al.* direct concentration model for northern pike are shown in Figure 8, including the 95% prediction limits. Prediction limits for the Harris *et al.* PIF models for walleye and northern pike are shown in Figure 9 and Figure 10. These figures also include data for the existing reservoirs that were used to develop the models. The *x* axis in these figures is an aggregate term that includes flooded area, total area and flow. The prediction intervals demonstrate the significant uncertainty associated with the current ability to predict peak fish mercury concentrations in new reservoirs. Without access to the original data used to develop the Johnston *et al.* and Bodaly *et al.* models, prediction intervals for peak fish mercury concentrations could not be derived for those models.

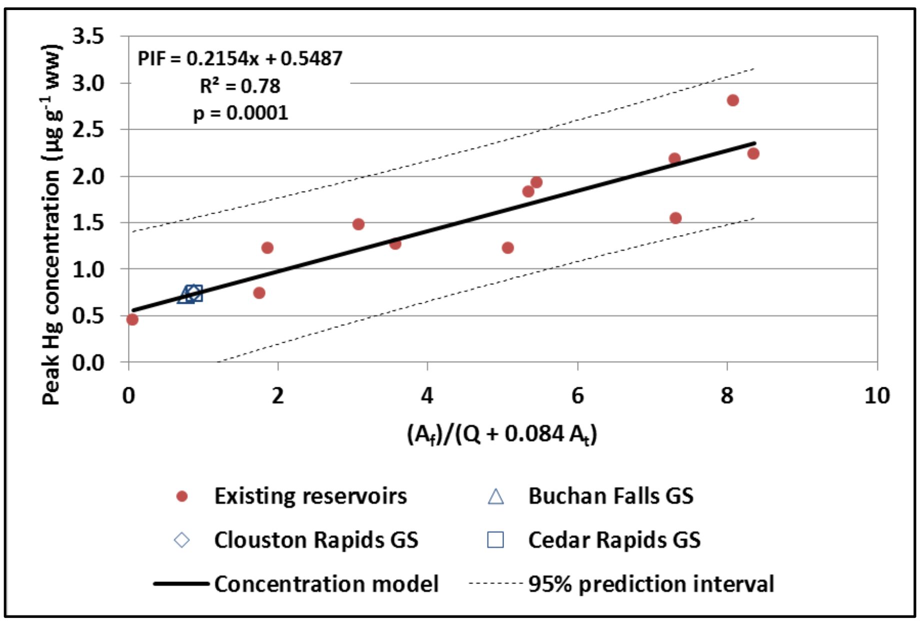

Figure 8. Peak mercury concentrations predicted by the Harris *et al.* model for 55 cm northern pike. Predictions for proposed generating stations in the Kapuskasing River Hydroelectric Project and existing reservoirs that were used to develop the model are shown. A_f = flooded area (km^2), A_t = total reservoir area (km^2), Q = mean annual flow ($km^3\ yr^{-1}$.)

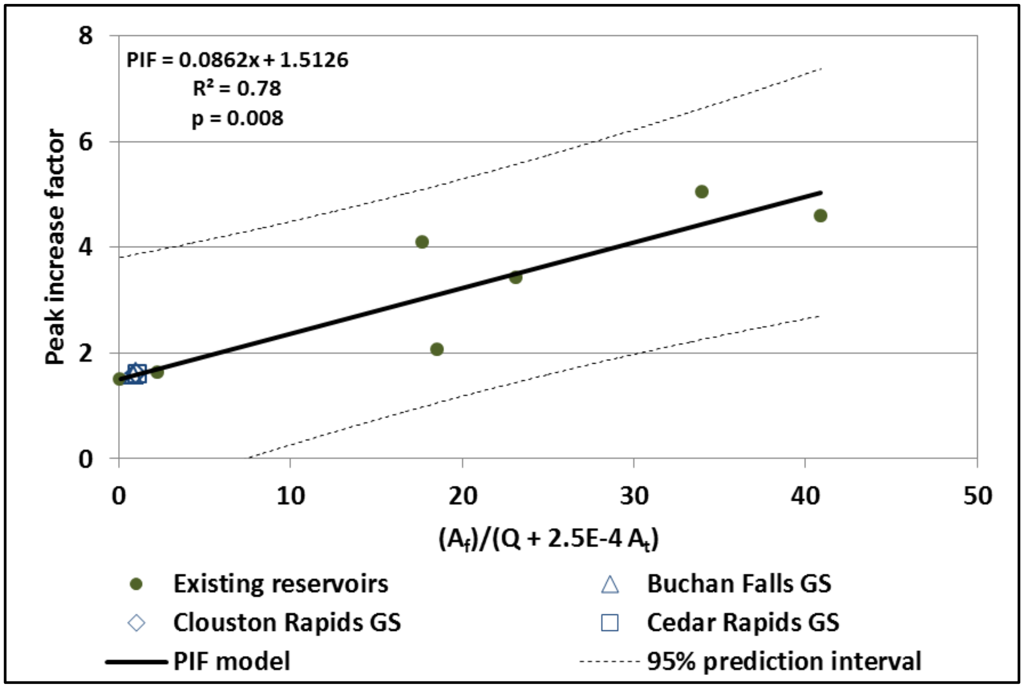

Figure 9. Peak increase factors predicted by the Harris *et al.* model for 40 cm walleye. Predictions for proposed generating stations in the Kapuskasing River Hydroelectric Project and existing reservoirs that were used to develop the model are shown. A_f = flooded area (km^2), A_t = total reservoir area (km^2), Q = mean annual flow (km^3 yr^{-1}.)

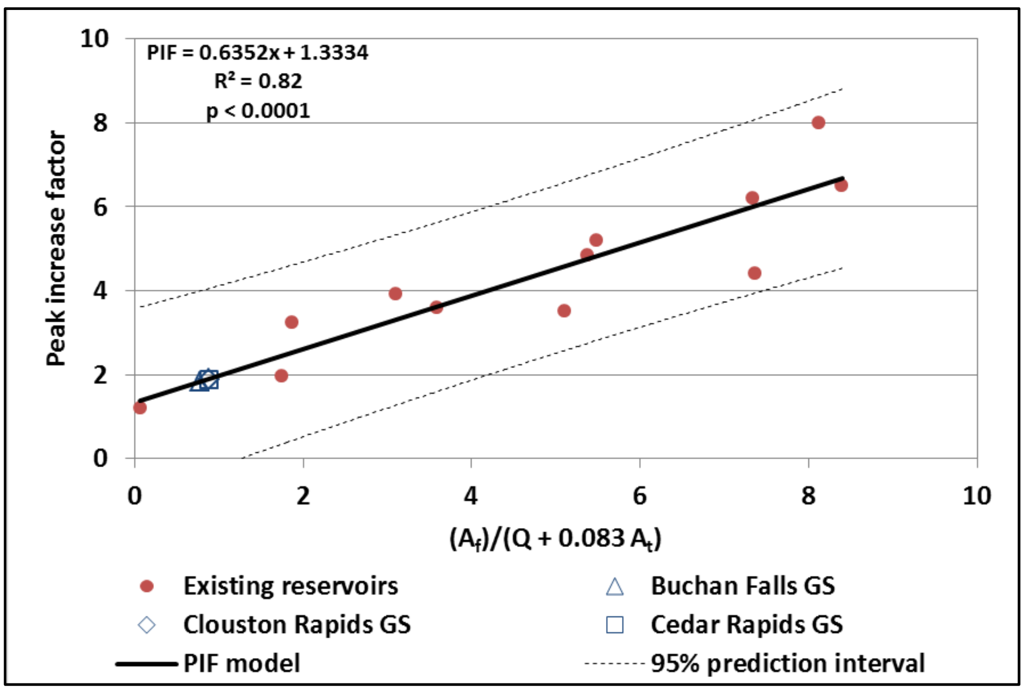

Figure 10. Peak increase factors predicted by the Harris *et al.* model for 55 cm northern pike. Predictions for proposed generating stations in the Kapuskasing River Hydroelectric Project and existing reservoirs that were used to develop the model are shown. A_f = flooded area (km^2), A_t = total reservoir area (km^2), Q = mean annual flow (km^3 yr^{-1}.)

6 Timing of the Fish Mercury Response

The timing of peak fish Hg concentrations and the subsequent long term recovery for the three facilities comprising the proposed Kapuskasing River Hydroelectric Project are expected to be within the range observed for other boreal reservoirs. Well-validated models to predict the timing of the response for specific sites are not yet available. Peak concentrations in lower trophic level fish are expected within a decade after flooding, while peak concentrations for higher level predators may occur within 3 to 13 years based on data from larger reservoirs in Quebec (Schetagne and Therrien, 2013; Schetagne *et al.*, 2003) and Manitoba (Bodaly *et al.*, 2007.) Fish Hg concentrations are expected to return to regional background levels within approximately 2 to 3 decades after flooding occurs. Recovery times are influenced by how quickly mercury is removed from an ecosystem. The short hydraulic residence time in proposed headponds at Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS (means of 24.5, 7.5and 4.4 hours) may contribute to a faster recovery period for the proposed development.

7 Conclusions

Several regression models were applied to predict peak mercury concentrations in the proposed headponds at Buchan Falls GS, Clouston Rapids GS and Cedar Rapids GS on the Kapuskasing River. Mercury concentrations in 40 cm walleye were predicted to increase from the baseline concentration of 0.89 $\mu g\ g^{-1}$ to a peak value of 1.2 to 2.1 $\mu g\ g^{-1}$ (wet muscle) in the three headponds. Concentrations in 55 cm northern pike were predicted to increase from 0.60 $\mu g\ g^{-1}$ to a peak of 0.7 to 2.0 $\mu g\ g^{-1}$. No models explicitly developed for smallmouth bass were available. Relative increases (*i.e.* peak/baseline concentration) predicted by the walleye and northern pike models were therefore applied to 35 cm smallmouth bass. This approach predicted peak concentrations of 0.8 to 1.8 $\mu g\ g^{-1}$, increasing from a baseline of 0.51 $\mu g\ g^{-1}$. Due to a lack of data for small hydroelectric projects, it is unclear which predictions are more likely to be accurate for the Kapuskasing River Hydroelectric Project.

Based on observations from other reservoirs, peak concentrations in lower trophic level fish are expected within a decade post-flood, while peak concentrations for higher level predators may occur within 3 to 13 years. Fish mercury concentrations are expected to return to regional background levels approximately 2 to 3 decades after flooding occurs.

There is significant uncertainty associated with all the models that predict peak concentrations, particularly for small hydroelectric sites where data are very limited. Given the uncertainty associated with predictions, it is critical that a fish mercury monitoring program be carried out post-flooding to provide information required for consumption advisories.

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