REVIEW OF KEEYASK PARTNERSHIP HUMAN HEALTH RISK ASSESSMENT ASSOCIATED WITH MERCURY IN FISH

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November 26, 2013

Presentation Outline

- The Issue
- Comments on HHRA
- Current Government Guidelines
- Mercury in other Canadian lakes
- Mercury in Supermarkets
- Current regulatory agency exposure limits
- Comprehensive literature review
- Modeling of mercury concentrations in hair

Presentation outline (cont'd)

- Health benefits of fish consumption
- Suggested risk management options
- Conclusions and recommendations

The Issue

- Methyl mercury in fish was identified as a human health concern by the Keeyask partnership, and federal and Manitoba regulators based on past experience with environmental impacts of hydroelectric development.
- According to the Final HHRA, under current conditions, it was concluded that "potential unacceptable risks could affect persons of any age if unrestricted consumption of the larger fish occurred on a frequent basis." Risk estimates as high as 4.7-fold to 15.1-fold above the Health Canada tolerable daily intake (TDI) were predicted.
- Following post-impoundment, there is a "potential for unacceptable health risks for persons who decide to frequently consume fish from Gull and Stephens lakes." Predicted risk estimates are up to 14.2-fold above the Health Canada TDI, for average size fish, and would be greater for larger fish.

The issue (cont'd)

- Risk assessment is a complex issue as the potential health effects of methyl mercury from fish consumption, must be weighed against the considerable health benefits with fish in the diet.
- Health risks also are very much dependent on consumption rates and the types of fish species typically harvested.
- KCN members have indicated they had already stopped or decreased the eating of fish and traditional foods due to concerns about mercury. There has been a reduction in domestic fishing and consumption of country foods as people are afraid to eat fish, resulting in an increase in store bought food.

Statements from Final HHRA

- As a result of the use of conservative assumptions, actual risks may be substantially lower than those predicted in the HHRA.
- Numerous fish in Gull and Stephens lakes currently have low (<0.2) and very low (<0.01) µg/g total Hg concentrations.
- Pike and walleye have average mean Hg concentrations >0.2 µg/g but less than 0.5 µg/g.
- For wild fish for subsistence purposes, there is no official recommendation from Health Canada or WHO, because of tremendous nutritional benefits of fish consumption.
- Manitoba Health and Health Canada have committed to working with the KCN and Manitoba Hydro on consumption advisories in a separate process.

Assumed Fish Consumption Rates by the Keeyask Cree First Nation

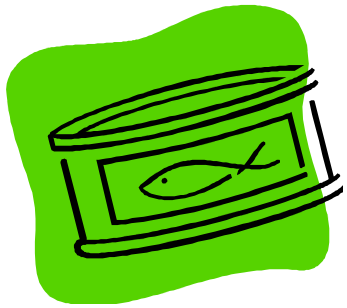
Fish Type	Serving Size for Young Child	Serving Size for Adult	Frequency of Consumption
Whitefish	100 g (or 3.5 ounces)[a]	400 g (or 14 ounces)[b]	Three times per week
Northern pike	100 g (or 3.5 ounces)	400 g (or 14 ounces)	Three times per week
Walleye	100 g (or 3.5 ounces)	400 g (or 14 ounces)	Three times per week
Sturgeon	100 g (or 3.5 ounces)	400 g (or 14 ounces)	Three times per week

a) Consumption rate = 43 grams/day
b) Consumption rate = 171 grams/day

Comparison with fish consumption guidelines

Health Canada fish consumption advice is intended to help maximize the nutritional benefits of eating fish while minimizing the risk of exposure to mercury.

- General Population — 150 g (or 5.3 ounces) per week
- Women of Childbearing Age — 150 g (or 5.3 ounces) per month
- Children 5 to 11 years old — 125 g (or 4.4 ounces) per month
- Children 1 to 4 years old — 75 g (or 2.6 ounces) per month
- Can of tuna ~ 170 g (or 4.9 ounces)



Comparison with fish consumption guidelines

Health Canada guideline is 0.5 ppm total mercury in commercial retail fish.

- Existing and predicted future fish Hg concentrations at Stephens Lake are below 0.5 ppm.
- Gull Lake existing Hg concentrations all fish <0.5 ppm. Predicted future Gull lake and Keeyask reservoir Hg concentrations <0.5 (whitefish, lake sturgeon), but may exceed 1.0 ppm in northern pike and walleye.

Manitoba Recreational Fishing Guidelines

(assuming present Hg concentrations in Slides 12 and 13)

Adherence to Manitoba angler's guidelines (2013) would allow for the following in Gull and Stephens lakes:

- Whitefish (<0.2 µg/g): 19 (227 g) meals/month general population (Risk = 0.36) and 8 (114 g) meals/month for women and children (Risk = 0.35).
- Walleye, northern pike and sturgeon (>0.2 and <0.5 µg/g): 8 meals/month general population (Risk = 0.43 to 0.49) and 3 meals/month for women and children (Risk = 0.38 to 0.44)

Manitoba Recreational Fishing Guidelines

(assuming future Hg concentrations in Slides 12 and 13)

- Whitefish (<0.2 ppm): 19 meals/month general population (Risk = 0.97) and 8 meals/month women and children (Risk = 0.96).
- Lake sturgeon (0.2 to 0.5 ppm): 8 meals/month general population (Risk 0.64) = and 3 meals/month women and children (Risk = 0.57).
- Walleye and northern pike (1.0 to 1.4 ppm): 3 meals/month general population (Risk =1.05 to 1.13) and none by women/children (Risk = 0).

Mercury in Other Canadian Lakes

Mercury in Fish from Canadian Lakes [mg/kg-WW]				
Source	Whitefish	Northern Pike	Walleye	Lake Sturgeon
Manitoba (First Nation Reserves)	0.06	0.20	0.16	0.20
Alberta	0.02 to 0.14	0.13 to 0.59	0.13 to 0.79	
Canada	0.17	0.56	0.41	0.31
Northern Canada	0.11	0.38	0.47	0.11

Mercury in Keeyask Study Area Gull Lake Fish [mg/kg-WW]				
Conditions	Whitefish	Northern Pike	Walleye	Lake Sturgeon
Present[a]	0.07	0.22	0.23	0.20
Post-impoundment	0.19[a]	1.0 to 1.3[b]	1.0 to 1.4[b]	0.30[a]

a) Similar to fish in other Canadian Lakes
b) Exceeds fish concentrations in other Canadian Lakes

Mercury in Supermarkets

Mercury in Fish from Commercial Outlets [mg/kg-WW]				
Source	Whitefish	Northern Pike	Walleye	Lake Sturgeon
Canada	0.10	0.25	0.37	0.1
United States	0.11	0.40	–	–
Ontario	0.29	0.24	–	–

Mercury in Keeyask Study Area Gull Lake Fish [mg/kg-WW]				
Conditions	Whitefish	Northern Pike	Walleye	Lake Sturgeon
Present[a]	0.07	0.22	0.23	0.20
Post-impoundment	0.19[a]	1.0 to 1.3[b]	1.0 to 1.4[b]	0.30[b]

a) Similar to fish in supermarkets
b) Exceeds fish concentrations in supermarkets

Mercury in Supermarkets

Mercury in Other Fish from Commercial Outlets [mg/kg-WW]					
Source	Salmon	Lake Trout	Halibut	Canned Tuna	
				Light/skipjack	**Albacore**
Canada	0.03	0.23	0.31	0.06 to 0.14	–
United States	0.048	0.35	0.25	0.12	0.33

Mercury in Keeyask Study Area Gull Lake Fish [mg/kg-WW]				
Conditions	Whitefish	Northern Pike	Walleye	Lake Sturgeon
Present[a]	0.07	0.22	0.23	0.20[a]
Post-impoundment	0.19[a]	1.0 to 1.3[b]	1.0 to 1.4[b]	0.30[a]

a) Similar to fish in other Canadian Lakes
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Current Regulatory Agency Exposure Limits

Summary of Health-based Government Exposure Limits for Methyl Mercury (MeHg)						
Parameter	Health Canada		WHO/JECFA		US EPA	ATSDR
	General population	Sensitive subgroup	General population	Sensitive subgroup	General population (including sensitive subgroups	
Tolerable Daily Intake (µg/kg bw/day)	0.47	0.2	0.47	0.23	0.1	0.3
Blood (µg/L)	20	8	20	11	5	15
Hair (mg/kg)	6	2	5 to 6	2.2	1	3
Uncertainty factor applied	10-fold	5-fold	10-fold	6.4-fold	10-fold	4.5-fold

Comprehensive literature review

- Health Canada proposed a toxicological reference of 10 mg/kg Hg in maternal hair as the approximate threshold for neuropsychological effects in sensitive subgroups.
- A 5-fold uncertainty factor to account for inter-individual variability to derive a hair benchmark of 2 mg/kg, and a tolerable daily intake (TDI) of 0.2 µg/kg body weight/day for women of reproductive age and children. The Manitoba government uses this TDI to determine fish consumption guidelines.
- Inconclusive evidence for adverse neurodevelopmental effects below 10 to 12 mg/kg in hair.
- Preponderance of evidence indicates that hair mercury levels at Health Canada's safe level of exposure for sensitive subgroups (2 mg/kg) or less are not associated with adverse effects.

Modeling Mercury in Humans

- Two models were used to predict mercury risks:
  1. Model that predicted exposures to mercury on a daily basis.
  2. A biologically based model that converted exposures to maternal hair concentrations.
- Hair concentrations provide a metric that can be:
  1. Compared to hair concentrations measured in Manitoba and other areas.
  2. Compared to hair concentrations in literature and toxicity studies.
  3. Used as additional information for weight-of-evidence regarding potential health risk.

Modeling Mercury Exposure

- Exposures were calculated with methods similar those used in the HHRA based on the following equation:

$$E = \frac{C_f \times IR}{BW}$$

Where

E = Exposure (mg/kg/day);

C_f = Concentration in fish (mg/kg-WW);

IR = Ingestion rate (kg/day); and

BW = Body weight (kg).

Modeling Mercury Exposure

- Annual distribution of fish dietary preferences was based on households in Ecozone three (Chan et al. 2012).

Fish	Percent Distribution (n=232)
Whitefish	22%
Pike	16%
Walleye	51%
Sturgeon	11%
Total	100%

Modeling Mercury Exposure

- Dietary distribution was used to calculate an overall weighted fish concentration that consists of all species of fish combined with the following equation:

$$C_f = \sum_{i=1}^{n} C_i \times PD_i$$

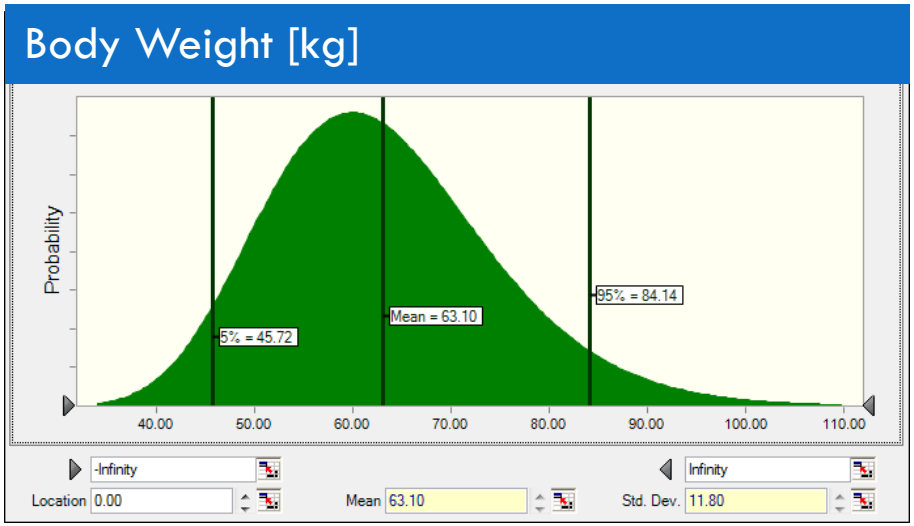
C_f = Overall concentration in fish consumed (mg/kg-WW);

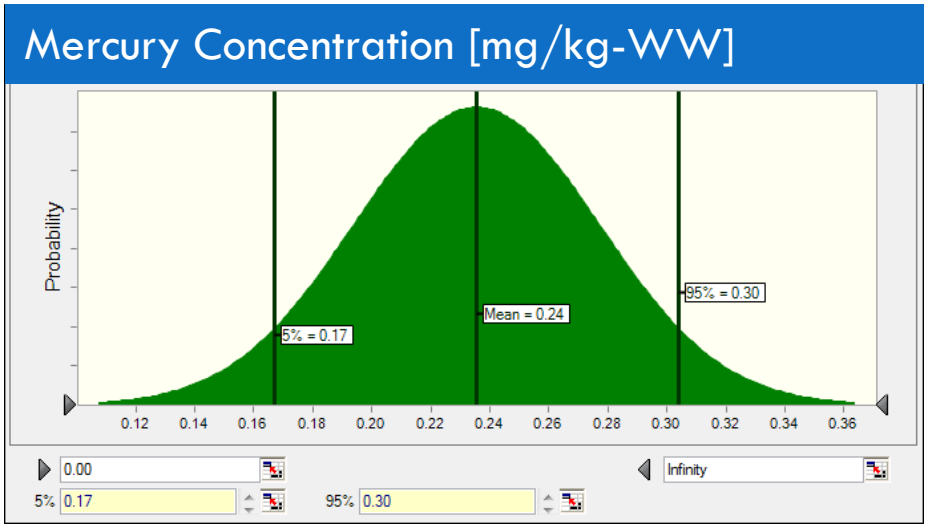
C_i = Concentration in fish species "i" (mg/kg-WW); and

PD_i = Percent distribution of fish species "i" in diet (%).

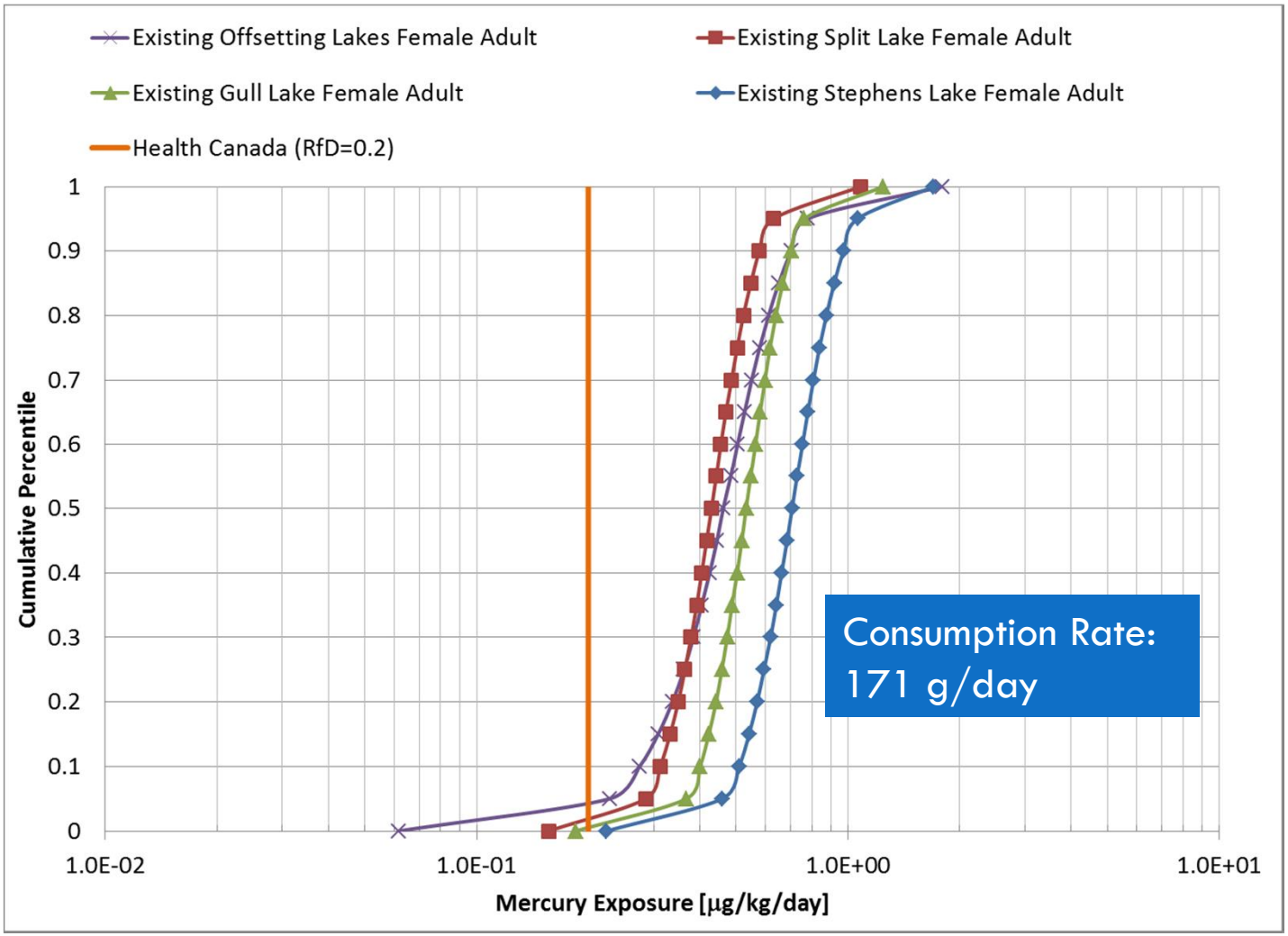
Modeling Mercury Exposure

- Input variables were modeled as distributions to predict exposures on a probabilistic basis:
  - Body weight [kg]
  - Mercury Concentrations in fish [ppm]

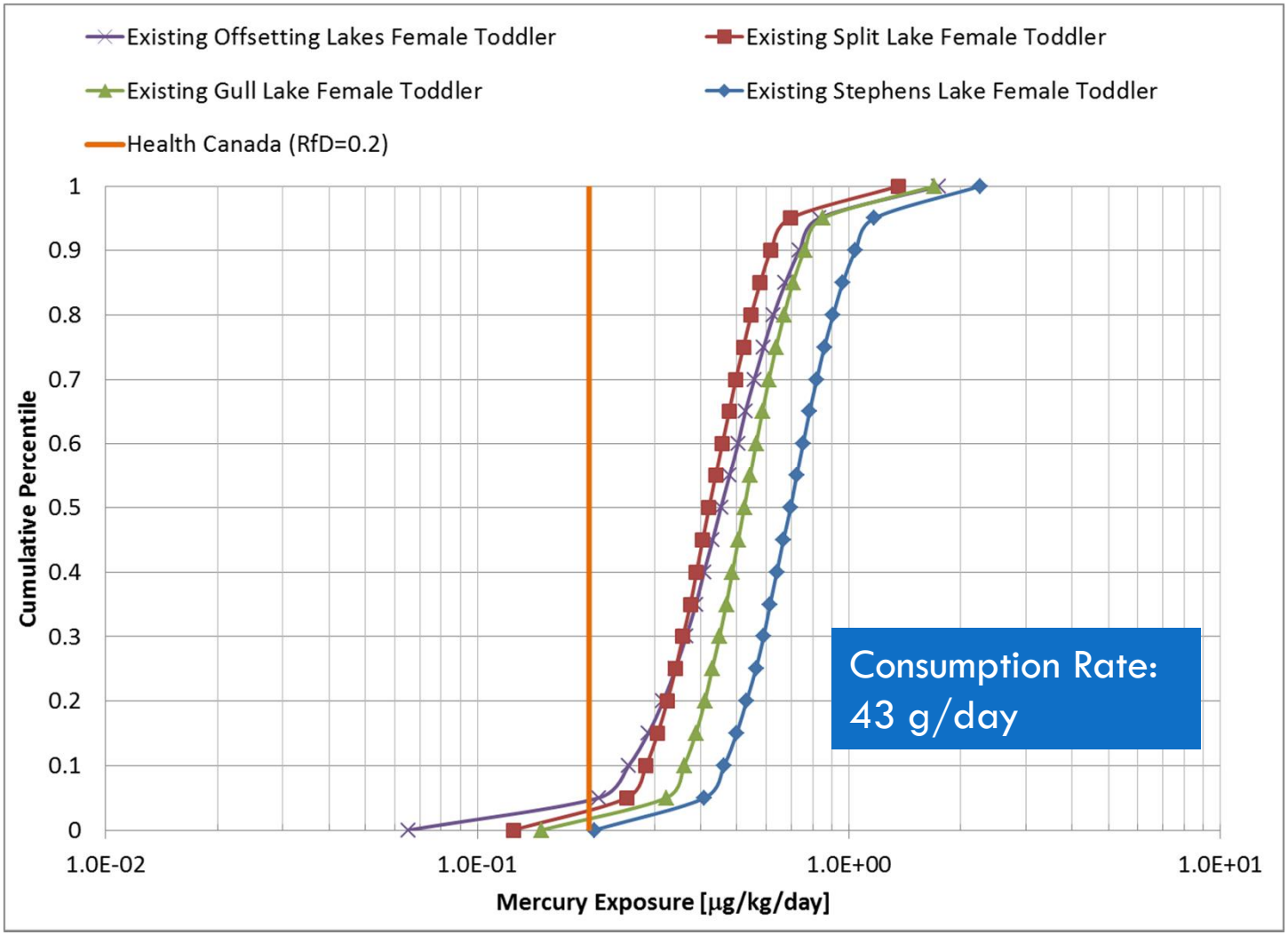




Modeling Existing Exposures - Adult



Modeling Existing Exposure - Toddler



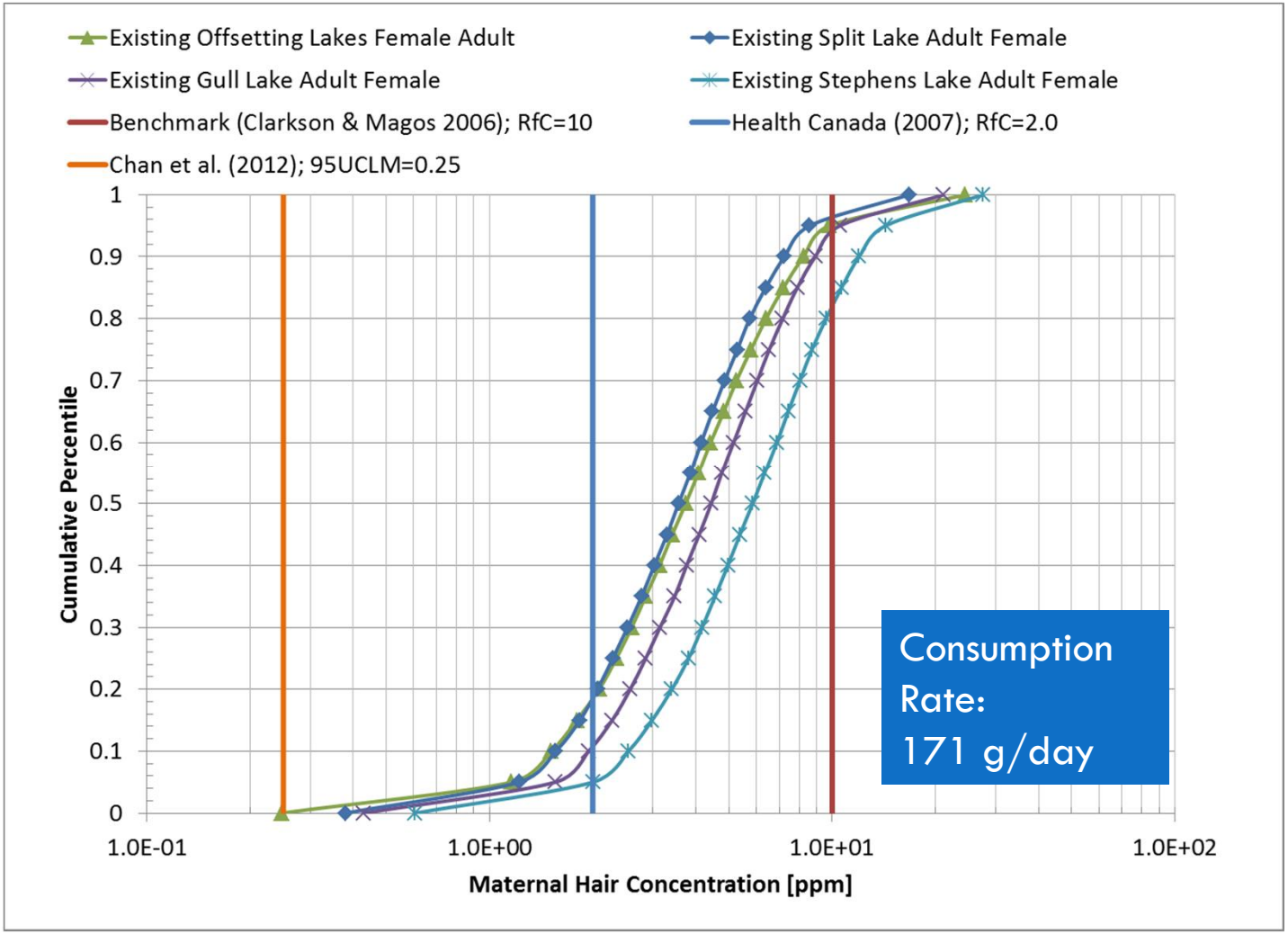
Modeling Concentrations in Hair

- A biologically based model was used to convert maternal exposures into expected distributions of hair concentrations.
- This was done for two purposes:
  1. Comparison to effect benchmarks and epidemiological studies; and
  2. Comparison to biomonitoring results.
- Model based on similar methods used by US EPA and Health Canada to derive exposure limits.

Biomonitoring Results

- FNFNES Study (Chan et al. 2012) estimated upper (95UCLM) hair concentration of 0.25 ppm among females aged 20 to 50 years of age living on First Nations reserves in Manitoba (n=138).
- Legrand et al. (2010) geometric mean blood levels of total mercury in the Canadian population was measured to be 0.69 μg/L. Equivalent to mean hair concentration of 0.2 ppm.

Concentration in Hair - Existing



Modeling with Modified Assumptions

- Two Assumptions in the mercury exposure model were re-evaluated to try an reduce the gap observed between predicted and measured hair concentrations:
  1. Fish consumption rates; and
  2. Proportion of methyl mercury in fish tissue.

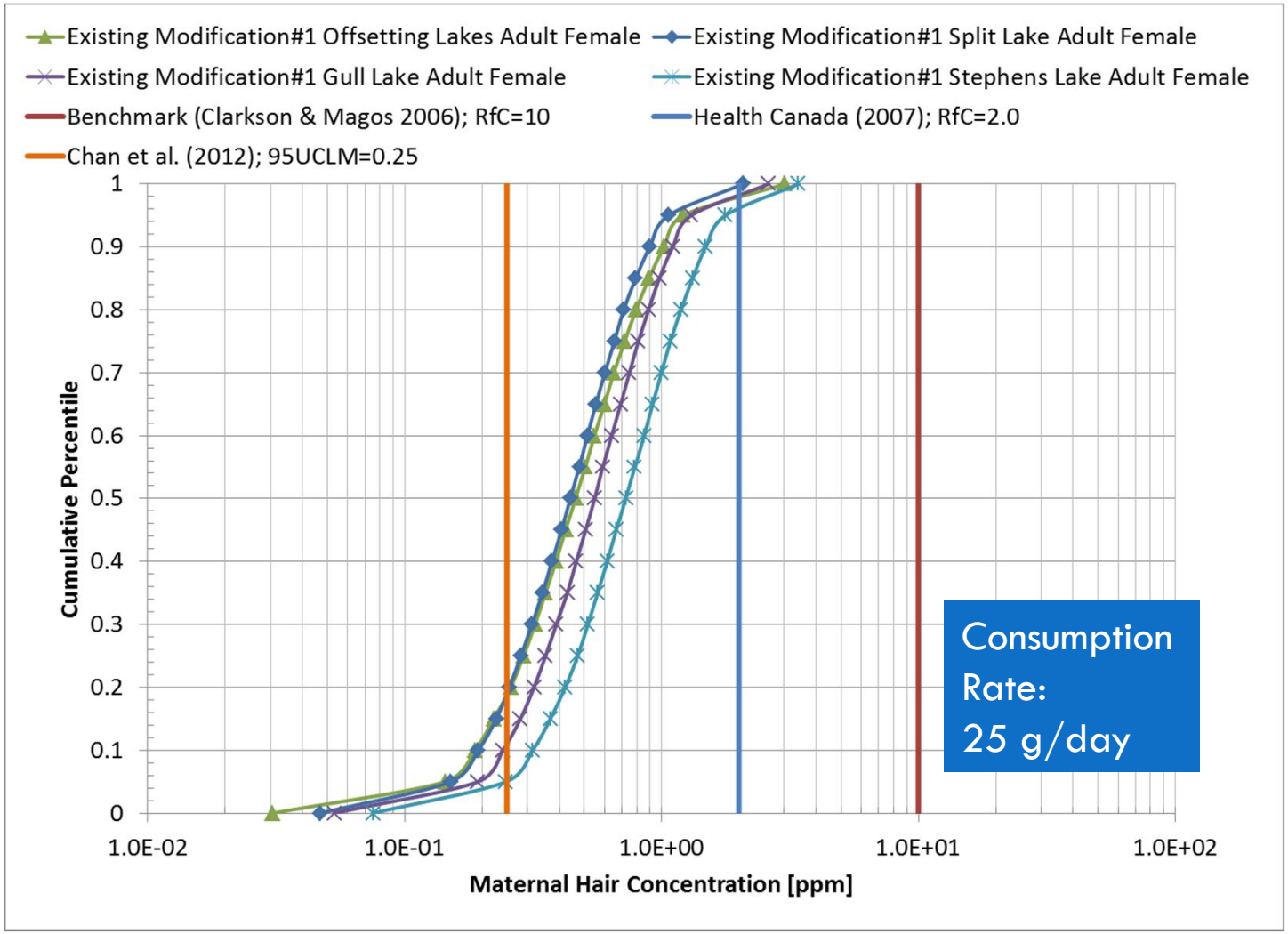
Manitoba FNFNES Study – Fish Consumption Rates

- Based on traditional food frequency questionnaire for the past year for all four seasons.
- 24-hour diet recall was based on in home interviews.
- Sub-sample (20%) selected for a second analysis to adjust for intra-individual variation.
- Provides a better indication of long-term consumption rates.
- In total 706 First Nation participants.

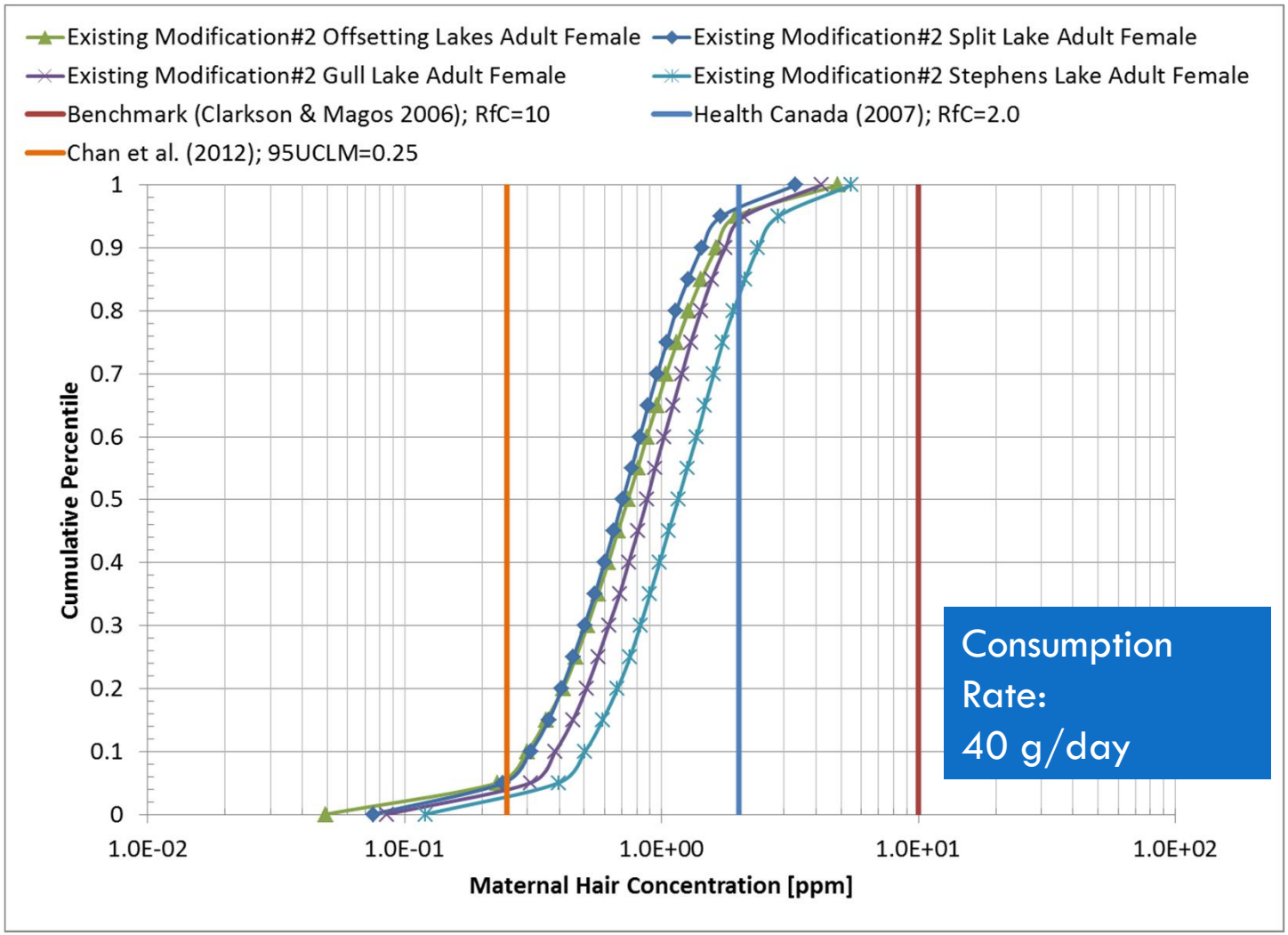
Modeling Consumption Rates

- FNFNES Study (Chan et al. 2012) presented data that yields an upper (95th percentile) consumption rate of 25 grams/person/day for females aged 20 to 50 (n=347).
- Health Canada (2007) recommends a subsistence adult fish consumption rate of 40 grams/person/day.
- These rates are substantially lower than the 171 grams/person/day assumed in the HHRA for whitefish, pike, walleye and sturgeon.
- Methyl mercury assumed to be 85% of total mercury measured in fish (Canuel et al. 2006).

Concentration Hair Existing - FNFNES



Concentration Hair Existing – Health Canada



Modeling Summary

- Hair mercury exposure modeling provides evidence that the predicted mercury health risks in the Keeyask HHRA are higher than expected.
- Models are helpful in identifying key uncertainties that can be reduced by collecting more information.
- Models can be used to identify consumption patterns that are relvant to the development of risk management plans.

Health Benefits of Fish Consumption

- Fish are a rich source of protein, essential fatty acids, vitamins and minerals.
- They are a nutritionally and culturally important food for many Canadians, especially Aboriginal groups or populations that consume wild fish. Fish are unique in their nutritional benefits due to low levels of saturated fats and high levels of the beneficial omega 3 polyunsaturated fatty acids (PUFAs), absent in most other foods.
- When health risks are perceived, traditional foods consumed by First Nations people are frequently replaced by energy dense and nutrient poor market food alternatives.
- Overall, it has been concluded that the benefits of modest fish consumption (1 to 2 servings per week) outweigh the risks among adults and excepting a few select fish species, among women of childbearing age.

Suggested Risk Management Options

- Health Canada and Manitoba government advise that choosing fish that are higher in Omega 3 fatty acids and lower in mercury is a means of balancing risks and benefits of fish consumption.
- Whitefish are a very good source of PUFAs, with estimated concentrations approaching that of Atlantic farmed salmon.
- Walleye, northern pike and sturgeon are much poorer sources of these nutrients.
- Thus, a shift in consumption towards more whitefish and less walleye and pike would maximize health benefits associated with fish consumption.
- For whitefish the recommended intake of 200 to 250 mg/day to optimize fetal development in pregnancy and lower cardiovascular risk can be met through even one meal per week of 150 grams.

Conclusions and Recommendations

- We agree that the highly conservative exposure assumptions in the Keeyask HHRA did substantially overestimate risks to local consumers. In particular, assumed fish consumption rates, based on consumer information provided by local communities, are the major contributor to predicted health risks.
- Health risks predicted in the HHRA for existing conditions would also apply to the "offsetting" lakes, indicating that risks may be predicted regardless of where the community harvests fish.
- Present average mercury concentrations in study area lakes are below the commercial guideline of 0.5ppm, are similar to or lower to mercury concentrations measured in other (un-impacted) Canadian lakes, and are similar or lower to mercury concentrations measured store-bought fish.

Conclusions and Recommendations (cont'd)

- While consumption recommendations were removed from the final HHRA, our review concludes that fish in Gull Lake and Stephens Lake can safely be consumed based on guidance provided by Health Canada (2007, 2010) and Manitoba government (2013).
- The additional information provided by CAC herein will allow for a more comprehensive weight-of-evidence approach to the development of future Keeyask fish consumption options and risk communication plans.