Calibration and Evaluation of a Dynamic Model that Projects Population Outcomes from Methylmercury Exposure from Local Fish Consumption

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Introduction

Contamination of fish has led to unacceptable levels of exposure to methylmercury for many regions of the US. Within highly exposed populations, such as subsistence fishers, the developing fetus is at particular risk for adverse effects. Regulatory agencies continue to consider how best to protect these populations. As a tool for these agencies, a dynamic model was developed to project mercury concentrations in common biomarkers of exposure in response to mercury concentrations in predatory fish from local waters. The model projects blood methylmercury, hair mercury, and cord blood concentrations for intake rates representing the mean, 90th, 95th, and 99th percentiles of populations of interest.

Model Design
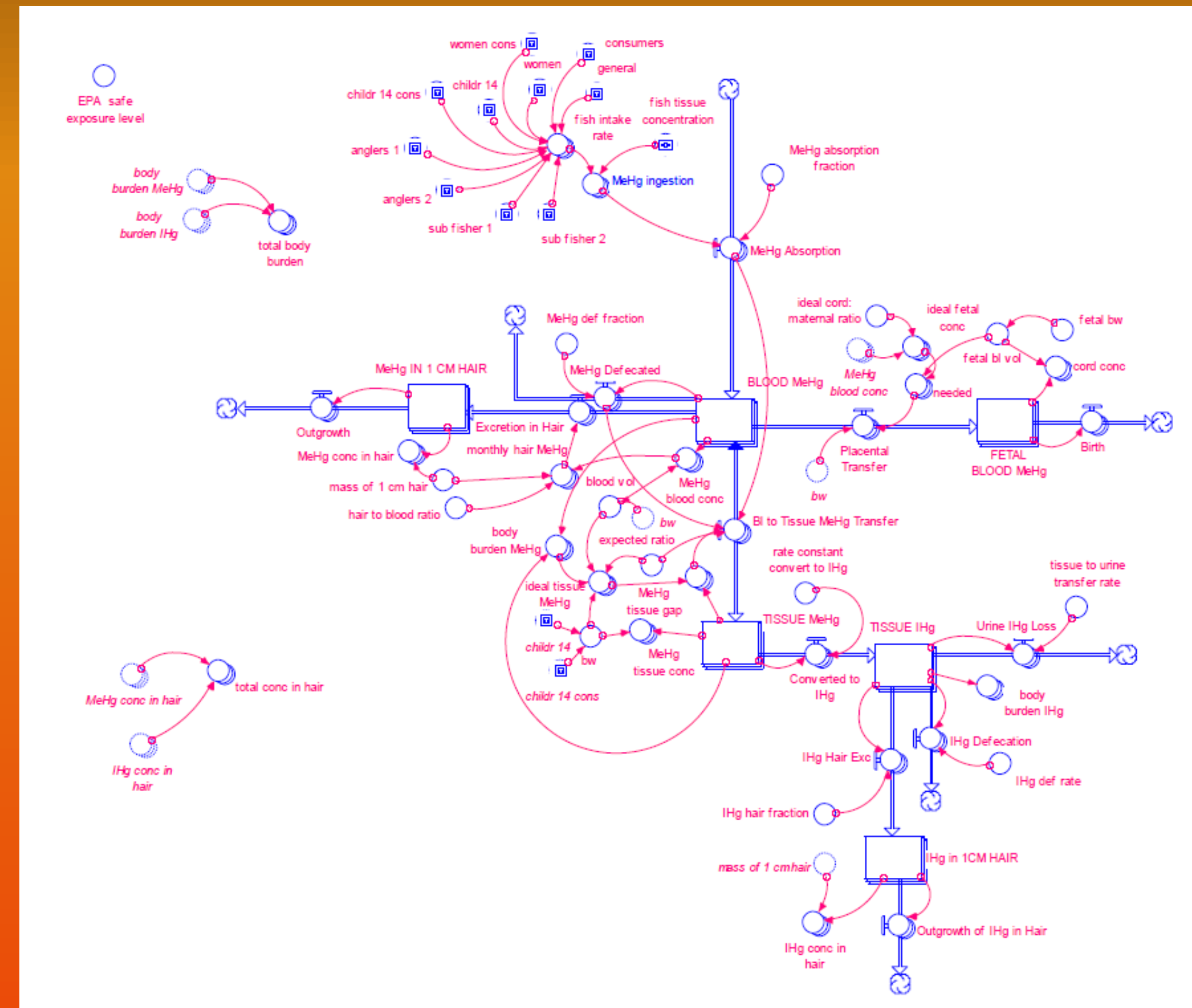
User Interface
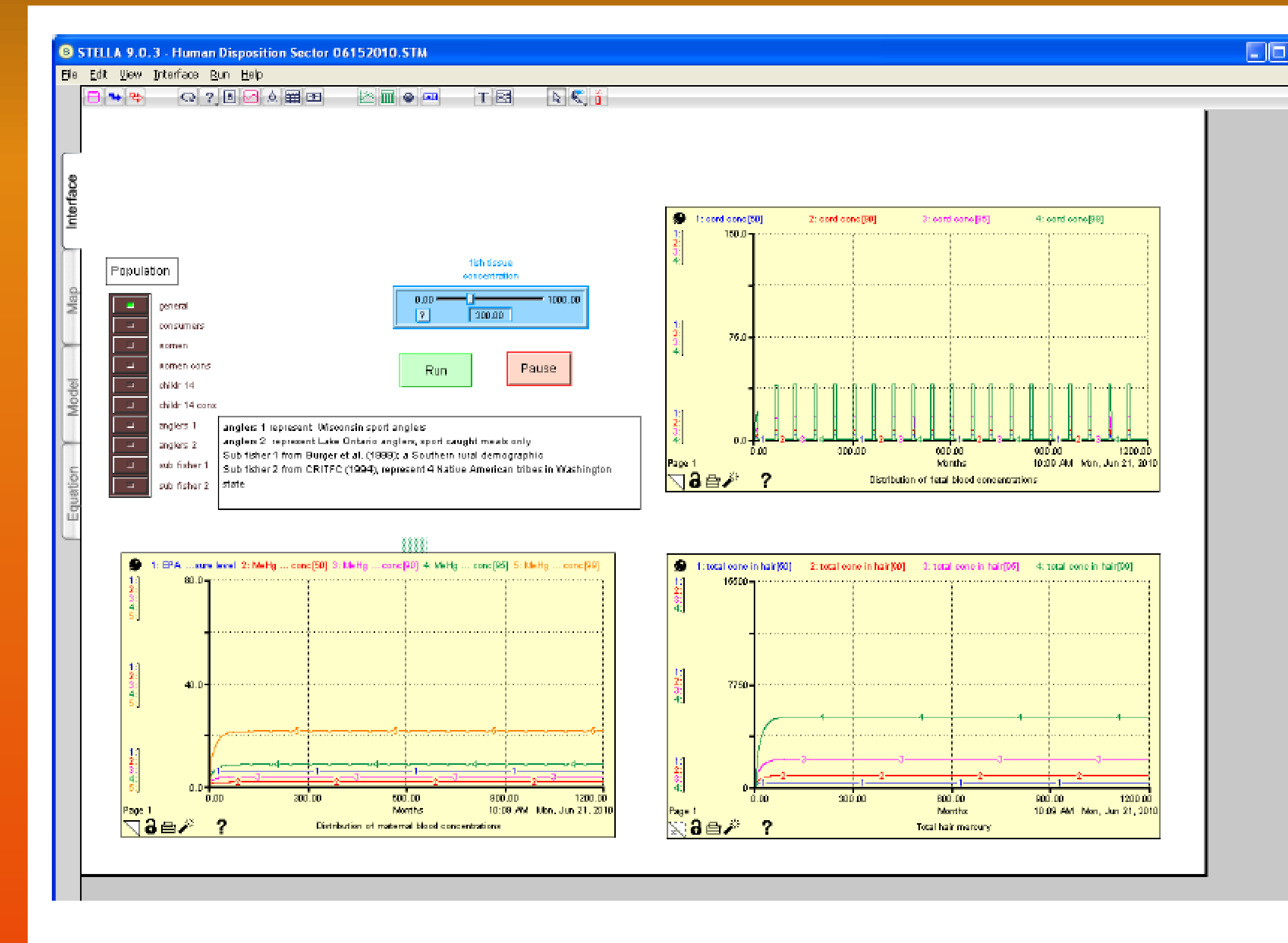

Population Descriptions

Distribution of intake rates of freshwater fish for populations in g/day

Population	Mean	90	95	99	Source	Description
		Percentile				
General	4.7	12.6	32.2	82.5	1	US population
Consumers only	68.0	170.8	224.8	374.7	1	US population that consumes fish
Women (15-44)	5.3	10.9	28.8	70.9	1	All women of childbearing age
Women (15-44) Consumers	61.4	148.8	185.4	363.6	1	Women of childbearing age who consume fish
Children (0- 14)	1.9	1.3	13.9	40.8	1	Children ages 0 to 14
Children (0-14) Consumers	45.7	108.4	136.2	214.6	1	Children ages 0 to 14 who consume fish
Anglers 1	7.4	20.6	24.6	41.1	1	Wisconsin sport anglers
Anglers 2	17.9	13.2	17.9	39.8	2	Lake Ontario sport fishers
Subsistence Fishers 1	55.5	150.0	200.0	338.0	3	Subsistence fishers on Savannah River
Subsistence Fishers 2	58.7	110.0	170.0	389.0	1	4 Native American tribes in Washington State

Conclusions

The developed model accurately projects the central tendency of biomarkers of exposure based on ingestion rates and fish tissue concentrations for populations of interest. It is a first step in linking environmental mercury levels to effects on nearby populations. With knowledge of the mercury concentration in fish from local waters, decision-makers can use the model to assess the portion of a population that is at risk and subsequently determine the decrease in fish tissue concentration needed to protect susceptible populations. The STELLA model depicts the disposition of mercury after ingestion in a simplified, yet understandable format, balancing accuracy, simplicity, and transparency. The model can be used as a tool to understand the impact of local fish consumption on local susceptible populations.

Calibration

1 Blood methylmercury

2 Hair total mercury

3 Fetal blood methylmercury
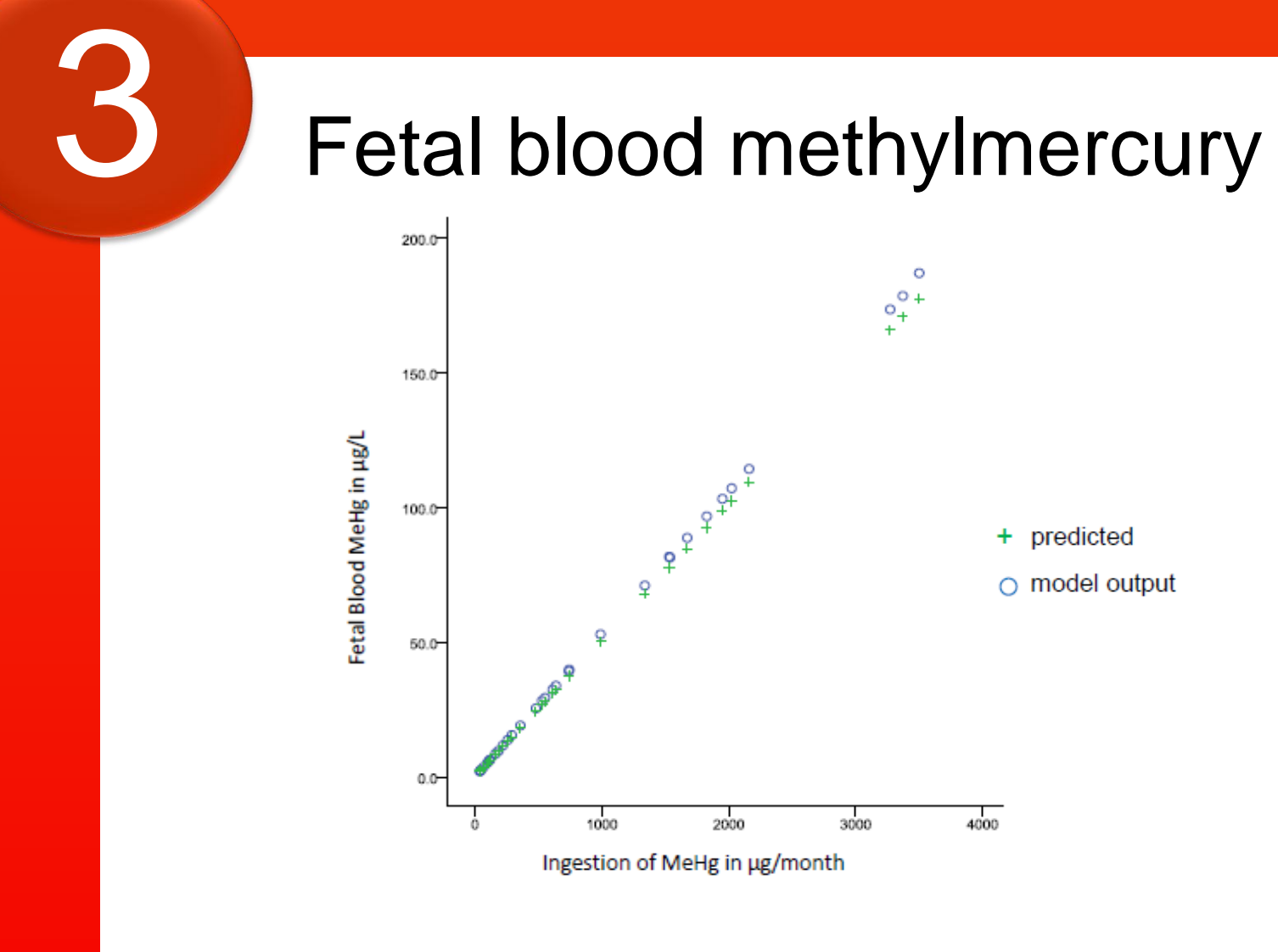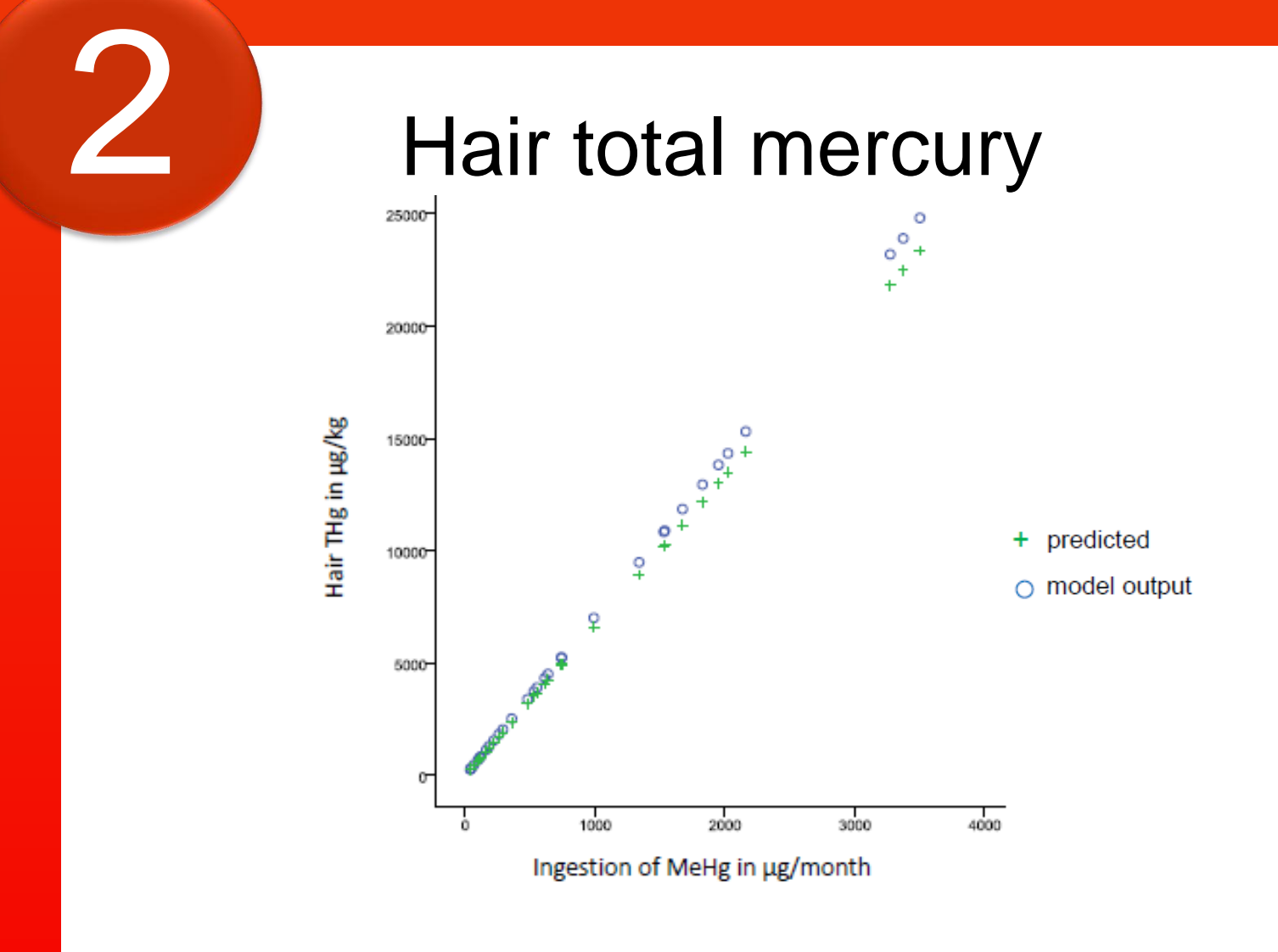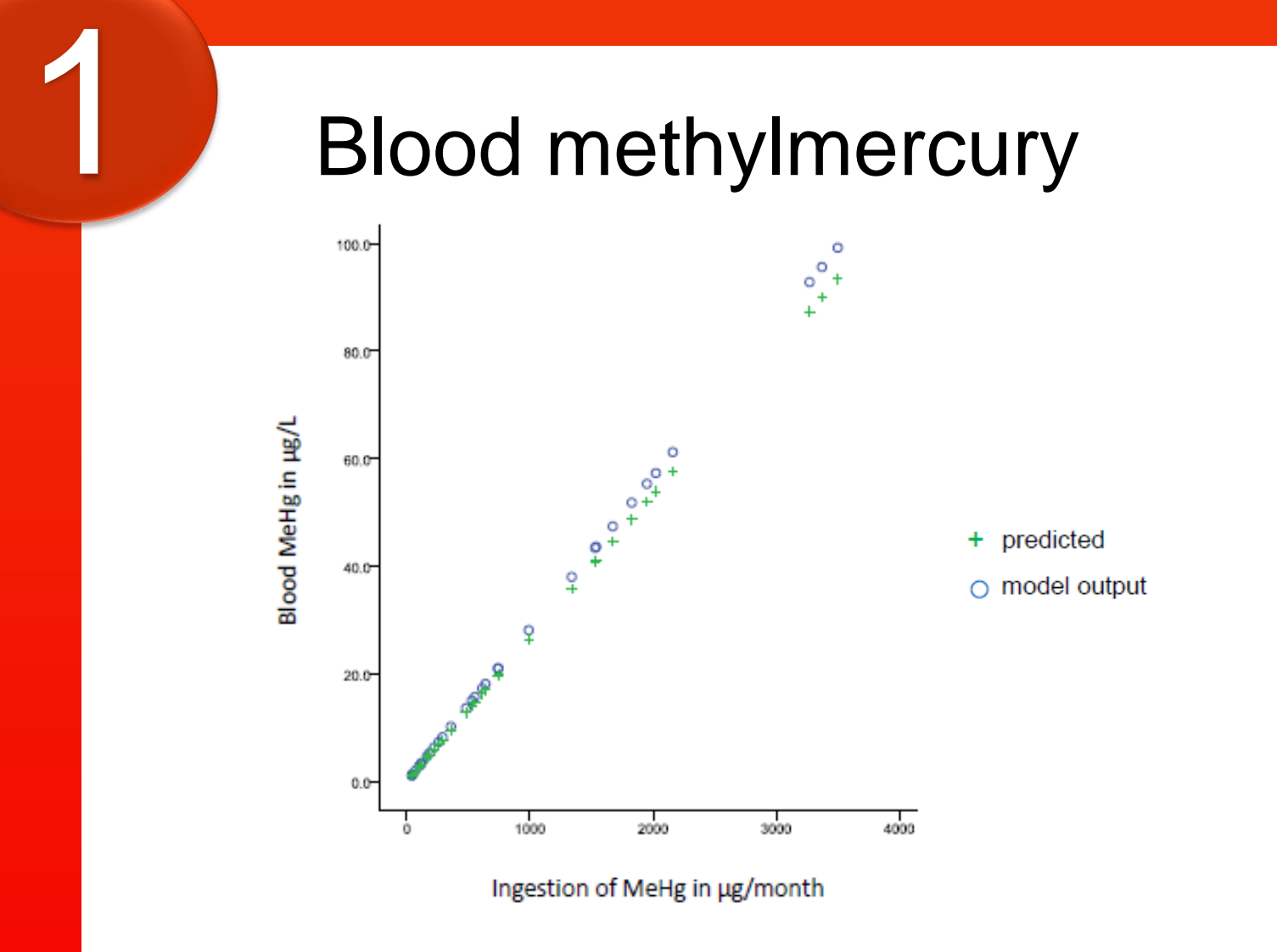
The model was calibrated to literature sources to maximize biomarker accuracy. Consistency was examined across the distribution of intake rates for all biomarkers. Chi-squared analyses were conduced using PASW Statistics 18, comparing the predicted values from literature sources to the observed model output.

1. The relationship between ingestion of methylmercury to blood methylmercury levels was calibrated to Sherlock et al. (1984)[4], which predicted a steady state blood methylmercury concentration of 0.8 µg/L for every 1 µg/day ingested.

2. The relationship between blood methylmercury to hair total mercury was calibrated according to Clarkson et al. (2007)[5]. A ratio of 250 µg/kg total hair mercury to 1 µg/L blood methylmercury was used.

3. The cord blood: maternal blood methylmercury ratio used to calibrate the model was taken from Stern and Smith (2003)[6]. Their study determined a central tendency ratio of 1.9 for the relationship between maternal and cord blood methylmercury.
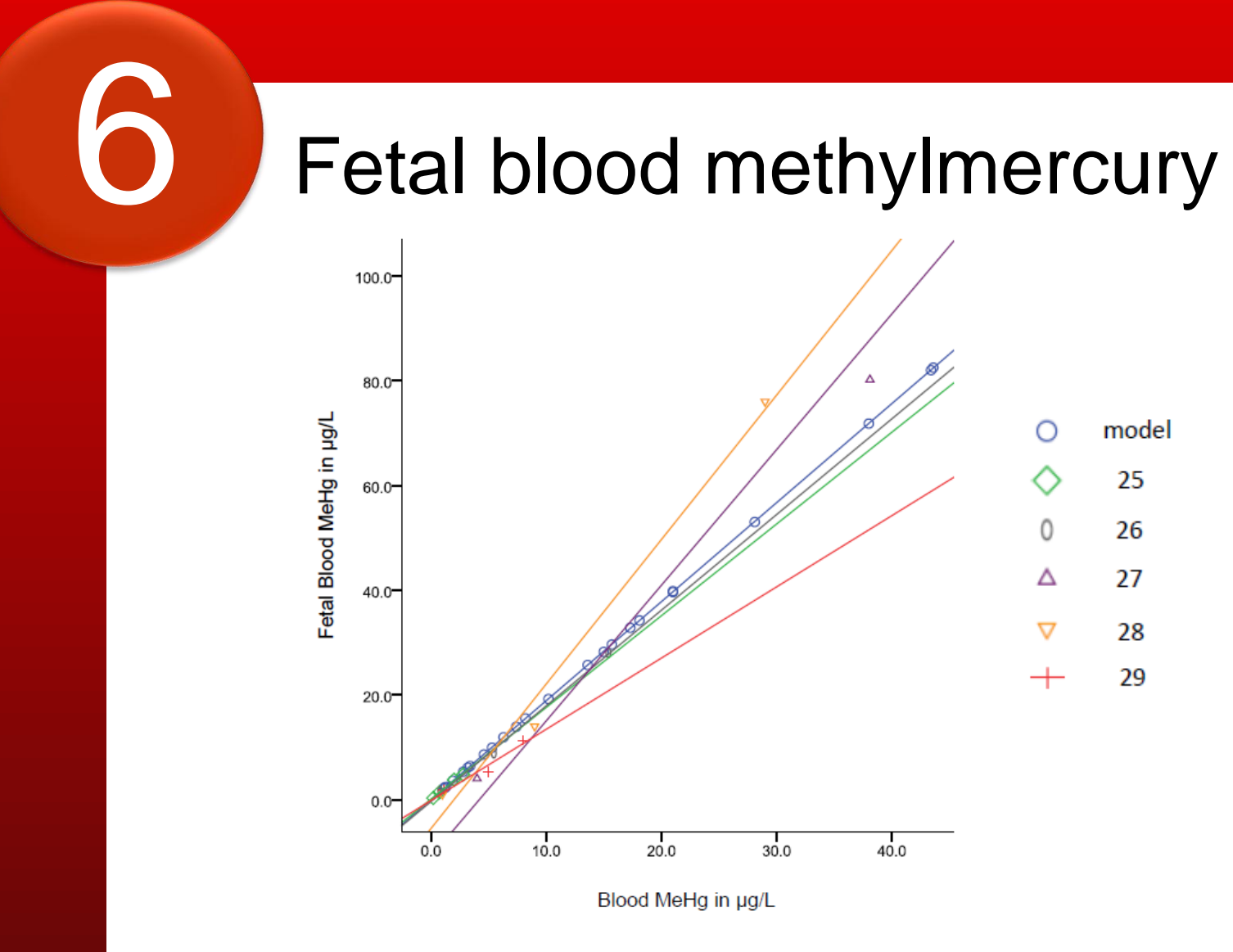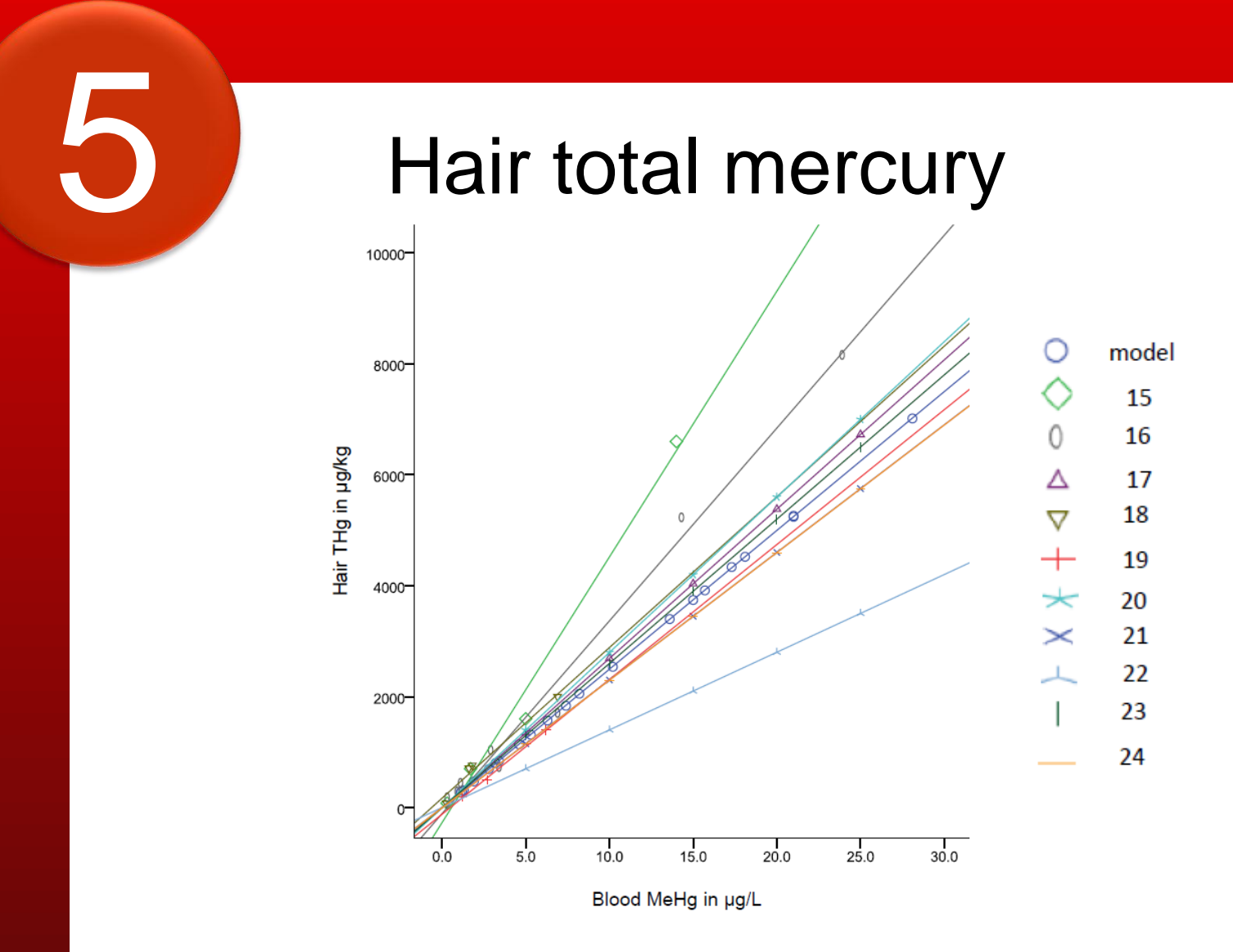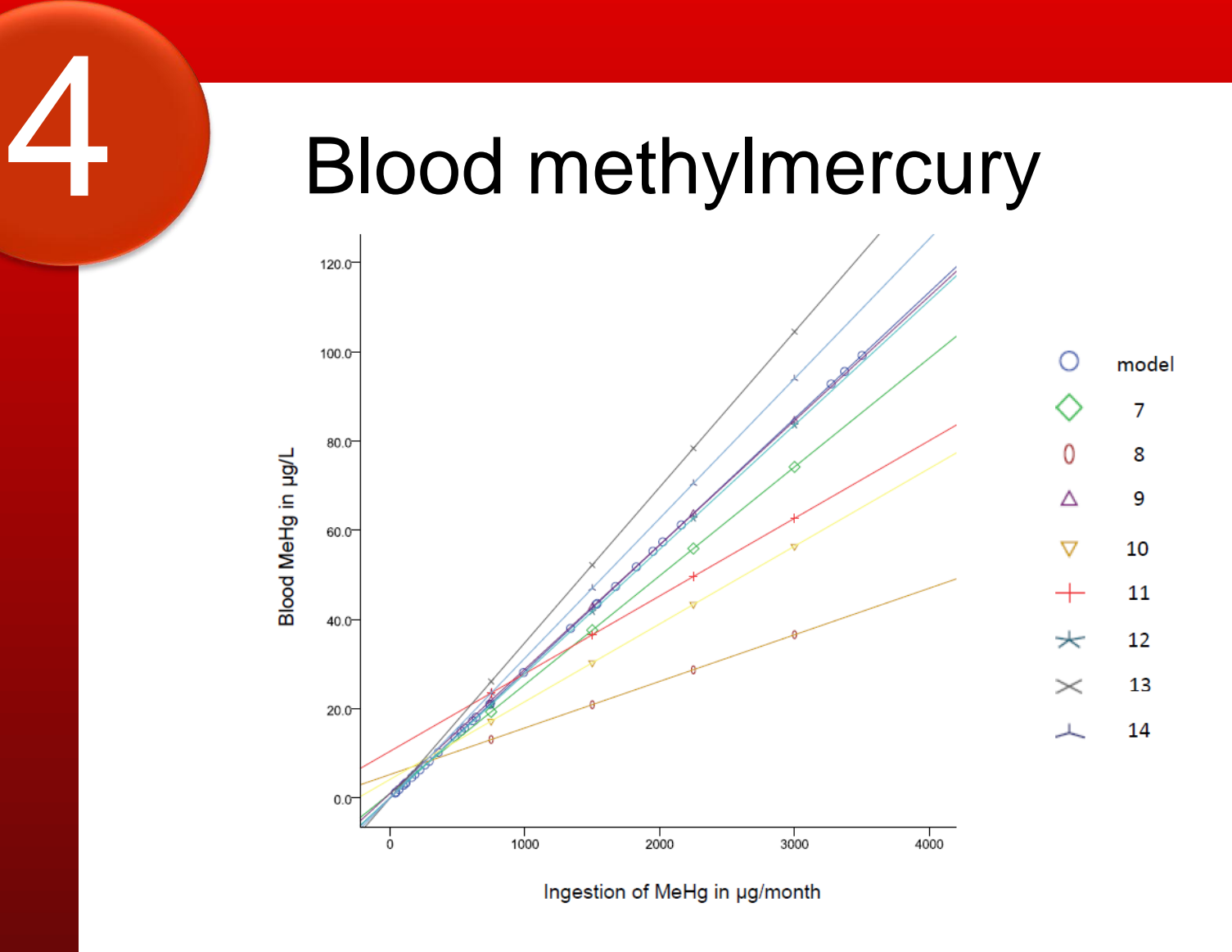
Chi-squared analyses showed not significant differences between model output and literature values (all p-values > 0.05). Scatterplots indicate the model slightly overestimates biomarker concentrations at the highest ingestion rates.

Chi-squared analysis p-values of expected versus observed model output.

Ingestion rate	Blood	Hair	Fetal Blood
mean	0.500	0.456	0.450
90	0.524	0.395	0.450
95	0.395	0.395	0.382
99	0.395	0.395	0.382

Evaluation

4 Blood methylmercury

5 Hair total mercury

6 Fetal blood methylmercury

For model evaluation, output was compared to additional literature sources to further strengthen confidence in the output. For literature sources providing regression equations, a range of values were input for the dependent variable. Other literature sources provided summary statistics which were used to generate regression equations. The mean and 95% confidence interval of the slopes of the literature sources for each biomarker were compared to the slope of model output.

Slopes of Regression Equations

Relationship	Literature Sources			Model Output
	mean	95% Confidence Interval		
		lower	upper	
4. blood methylmercury and ingestion	0.024	0.008	0.040	0.028
5. total hair mercury and blood methylmercury	283	235	331	250
6. fetal and maternal blood methylmercury	2.1	1.5	2.6	1.9

The slopes of model output fall within the 95% confidence interval of the slopes of literature sources for all evaluated relationships, showing no difference between model output and literature sources.

Literature Sources

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