Risk Assessment on Mercury Exposure: Meeting with the Independent Expert Advisory Committee

Laurie Hing Man Chan, Ph.D.
Professor and Canada Research Chair
in Toxicology and Environmental Health
University of Ottawa

Teleconference Call
15 February 2018

Six Topics

- Overview of mercury issues
- Basic concept of toxicology and risk assessment
- Health Canada Guideline levels
- WHO/FAO Risk-Benefit Assessment
- Previous work
  - Inuit Health Survey
  - First Nation Food Nutrition and Environment Study
- Comments on 2 monitoring results and future scenario

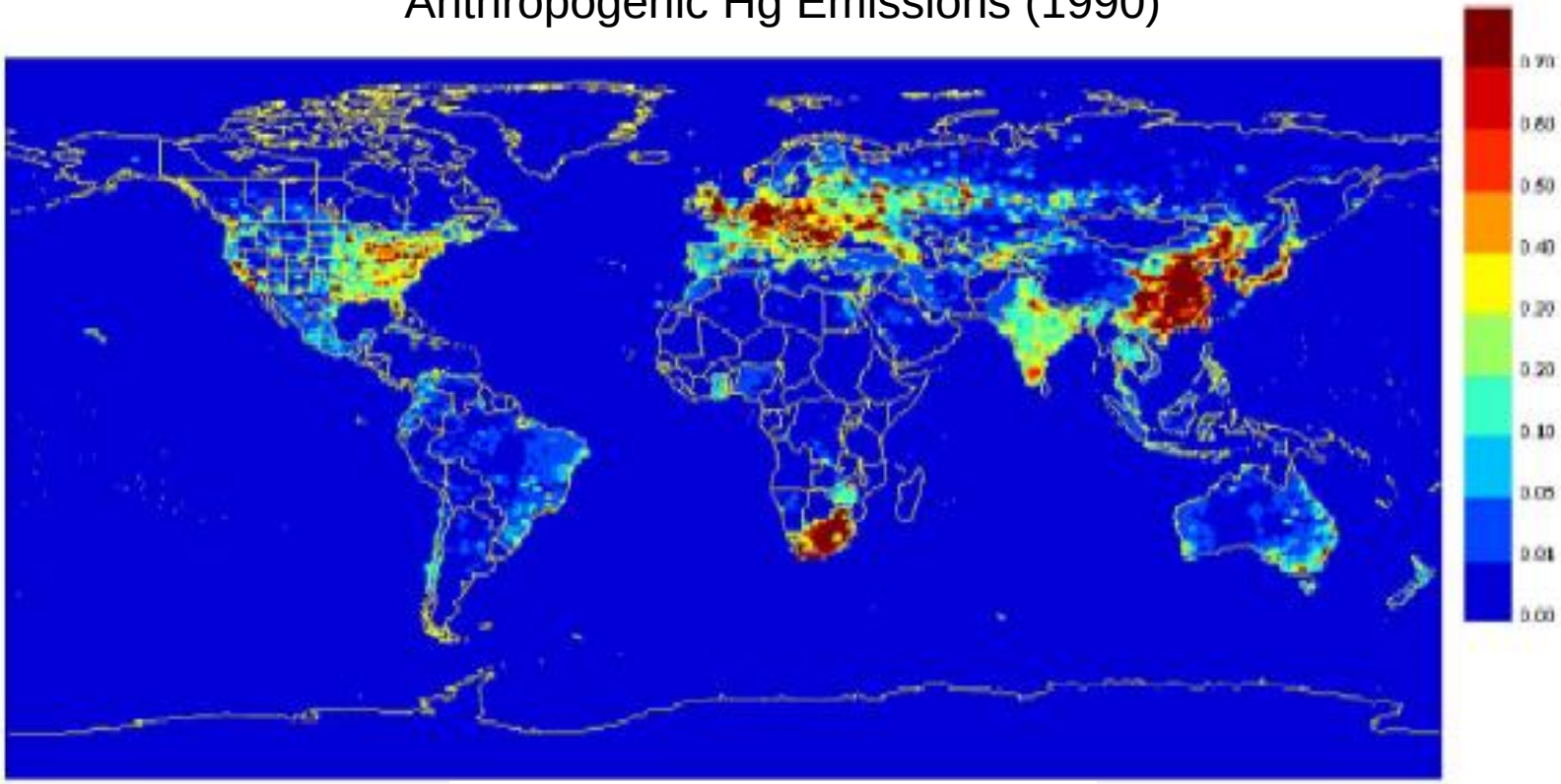
1. Mercury – some background

New problems arise from an old toxin

- Mined for over 2000 years
- Known neurotoxicant since the 18th century
- Public health concern started since poisoning in Minamata

Why care about Hg?

Anthropogenic Hg Emissions (1990)



(Dastoor et al, 2004)

- **potent neurotoxicant**
- **levels ↑ 3 - 6x pre-industry**
- **2 - 8 kilotons released per year**
- **biomagnification factor: up to 1 million**

Environmental Science & Technology

Critical Review

pubs.acs.org/est

Mercury as a Global Pollutant: Sources, Pathways, and Effects

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ABSTRACT: Mercury (Hg) is a global pollutant that affects human and ecosystem health. We synthesize understanding of sources, atmosphere-land-ocean Hg dynamics and health effects, and consider the implications of Hg-control policies. Primary anthropogenic Hg emissions greatly exceed natural geogenic sources, resulting in increases in Hg reservoirs and subsequent secondary Hg emissions that facilitate its global distribution. The ultimate fate of emitted Hg is primarily recalcitrant soil pools and deep ocean waters and sediments. Transfers of Hg emissions to largely unavailable reservoirs occur over the time scale of centuries, and are primarily mediated through atmospheric exchanges of wet/dry deposition and evasion from vegetation, soil organic matter and ocean surfaces. A key link between inorganic Hg inputs and exposure of humans and wildlife is the net production of methylmercury, which occurs mainly in reducing zones in freshwater, terrestrial, and coastal environments, and the subsurface ocean. Elevated human exposure to methylmercury primarily results from consumption of estuarine and marine fish. Developing fetuses are most at risk from this neurotoxin but health effects of highly exposed populations and wildlife are also a concern. Integration of Hg science with national and international policy efforts is needed to target efforts and evaluate efficacy.

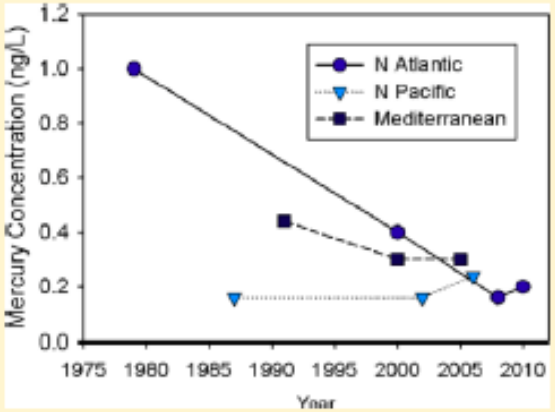
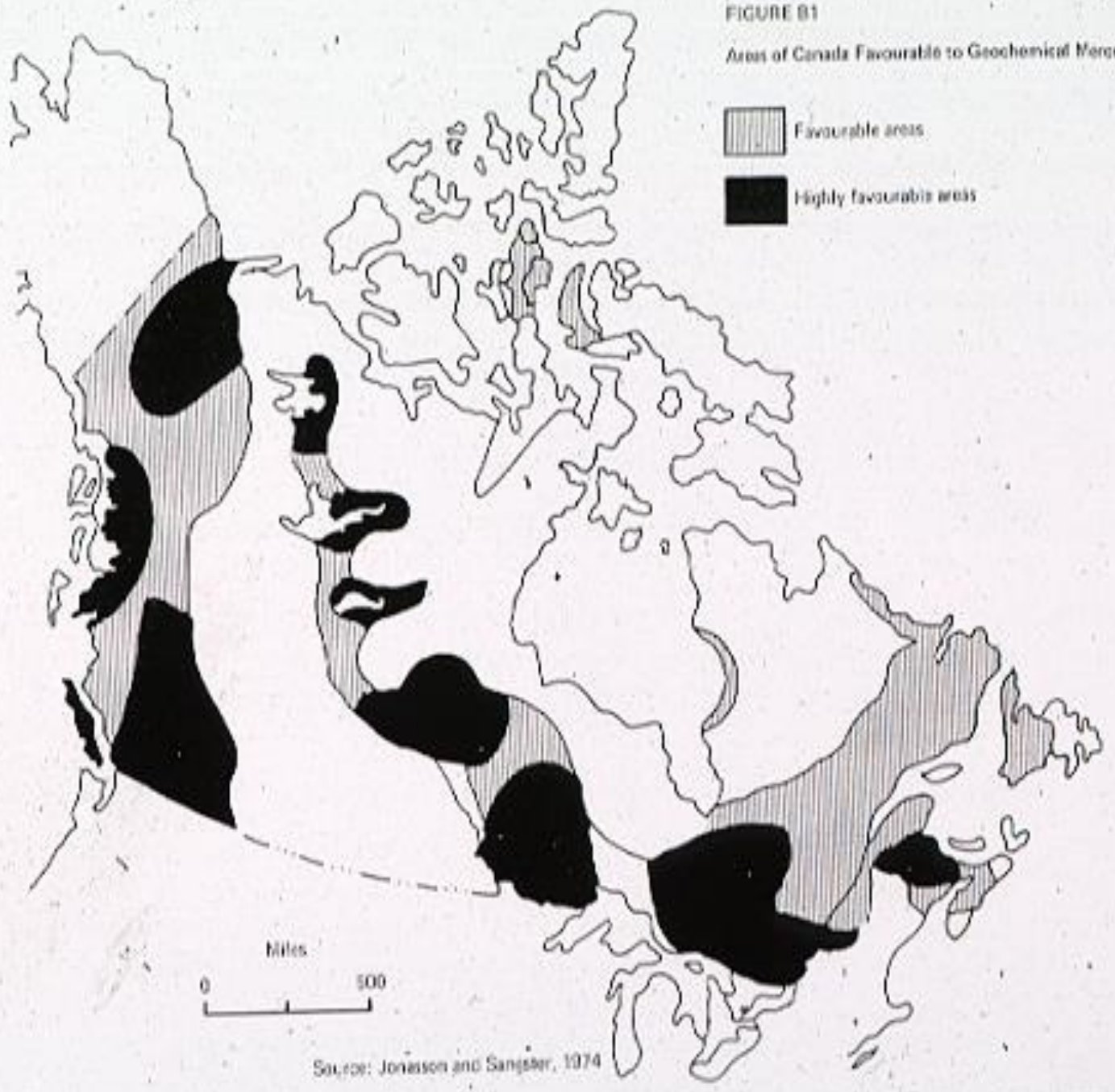


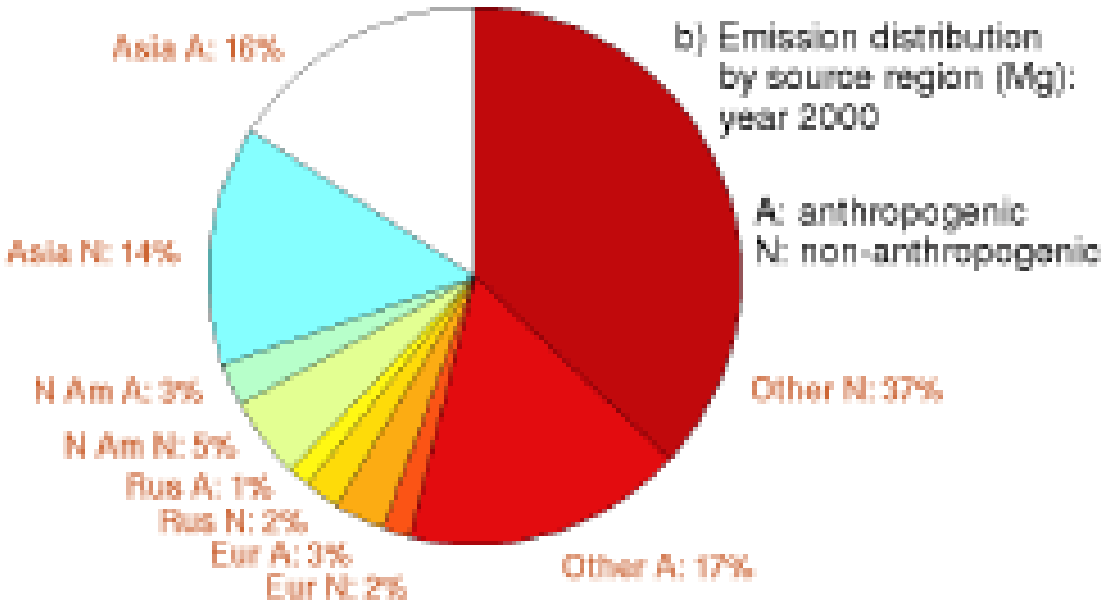
FIGURE B1

Areas of Canada Favourable to Geochemical Mercury



Source: Jonasson and Sangster, 1974

Natural vs Anthropogenic sources of Hg globally



Durnford et al. 2010

Mercury Studies
among the Cree of Eeyou Istchee

Deborah Schoen, MPH, Eng
Elizabeth Robinson, MD

March 2005.

Miyupimaatisiwin aa uhchi pi
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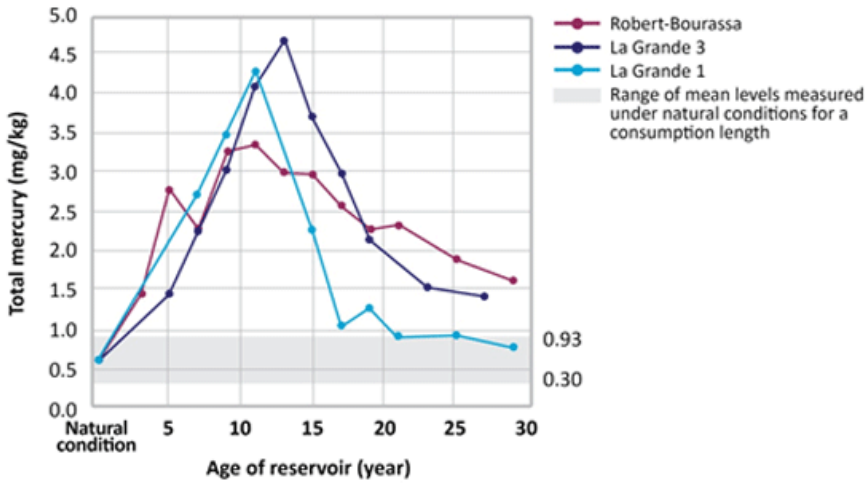
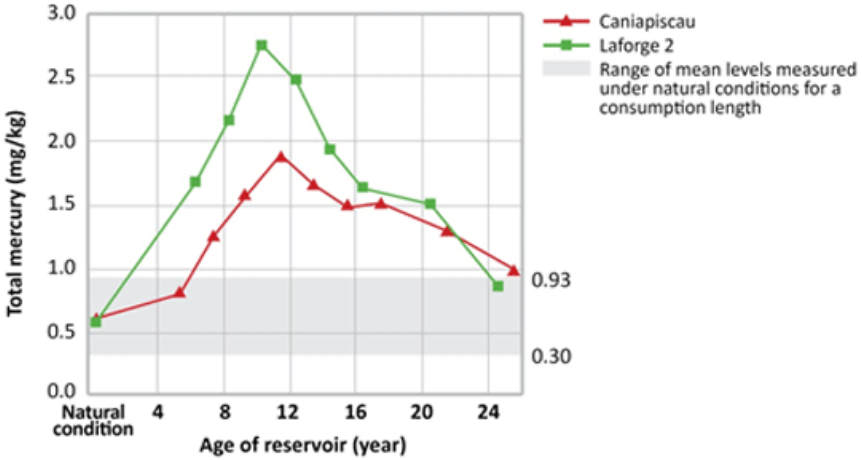
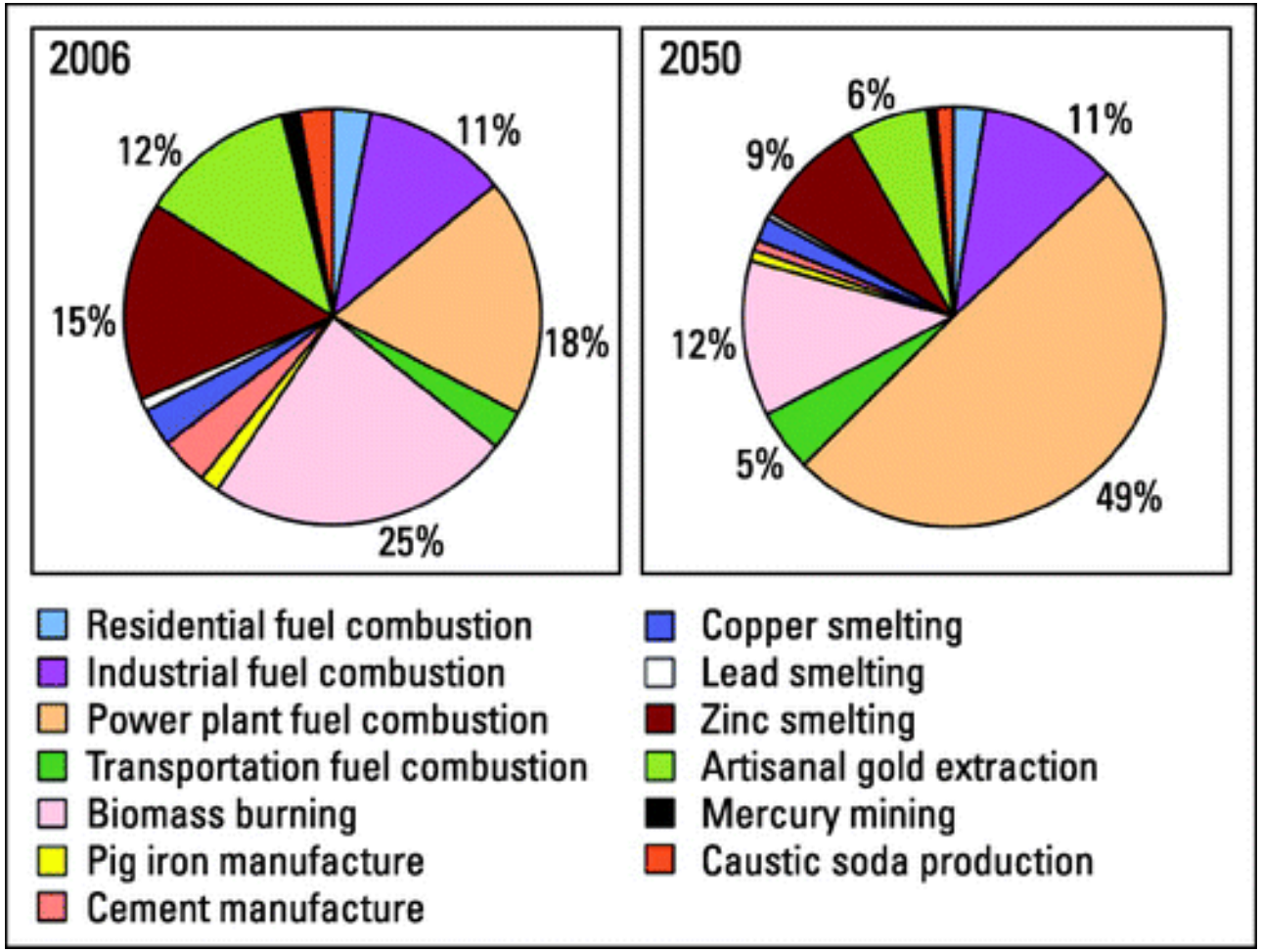
Public Health De





Conseil Cri de la santé et des services sociaux de la Baie James
Cree Board of Health and Social Services of James Bay

Global emission of Hg will increase by 50% in 2050

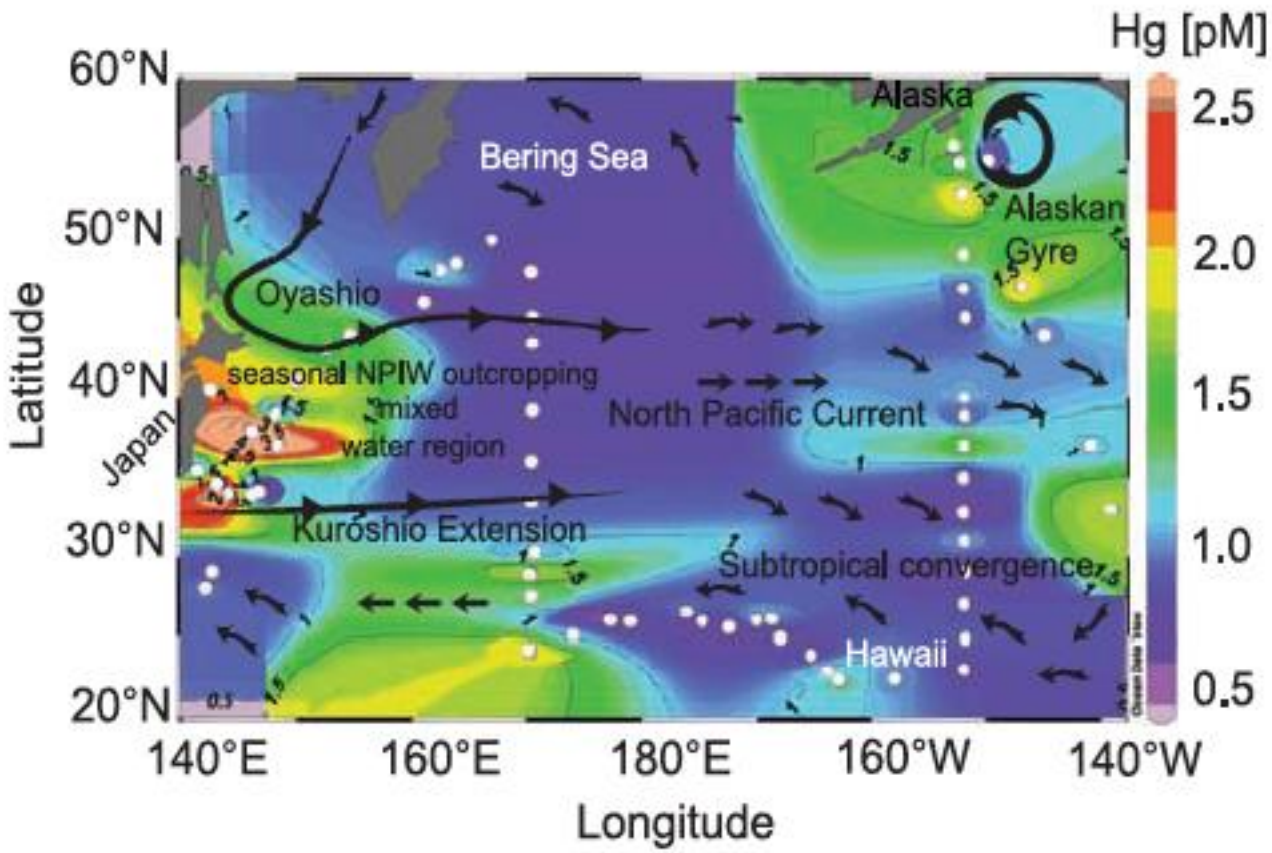


Streets DG, Zhang Q, Wu Y. Environ Sci Technol. 2009 Apr 15;43(8):2983-8.

Prosperity needs more power

China has been **building about two power stations every week in the last 2 decades**

Oceanic transport of Hg in the Pacific



Sunderland et al GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 23, GB2010, 14 PP., 2009

Mercury from Asia reaching Canada and the Arctic by air currents

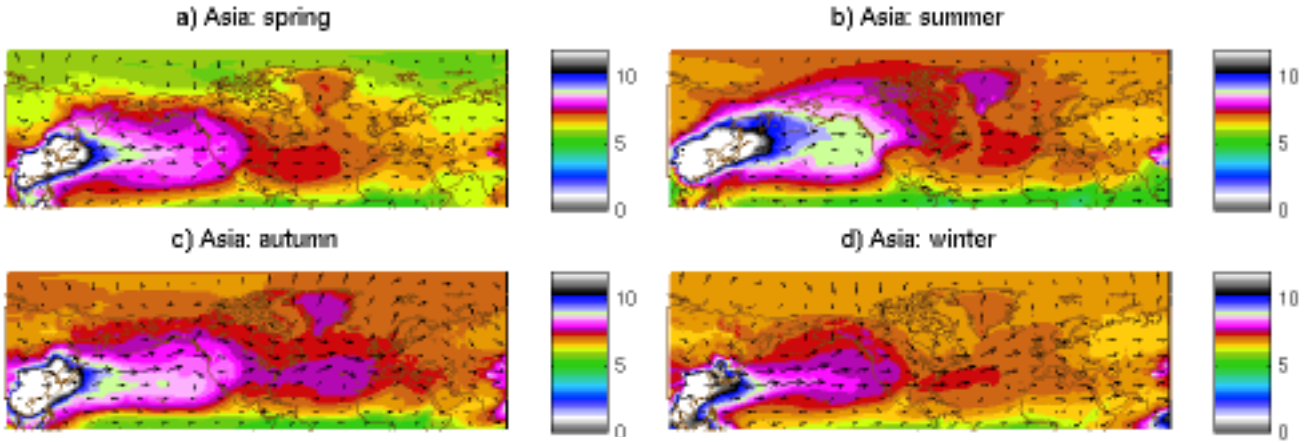
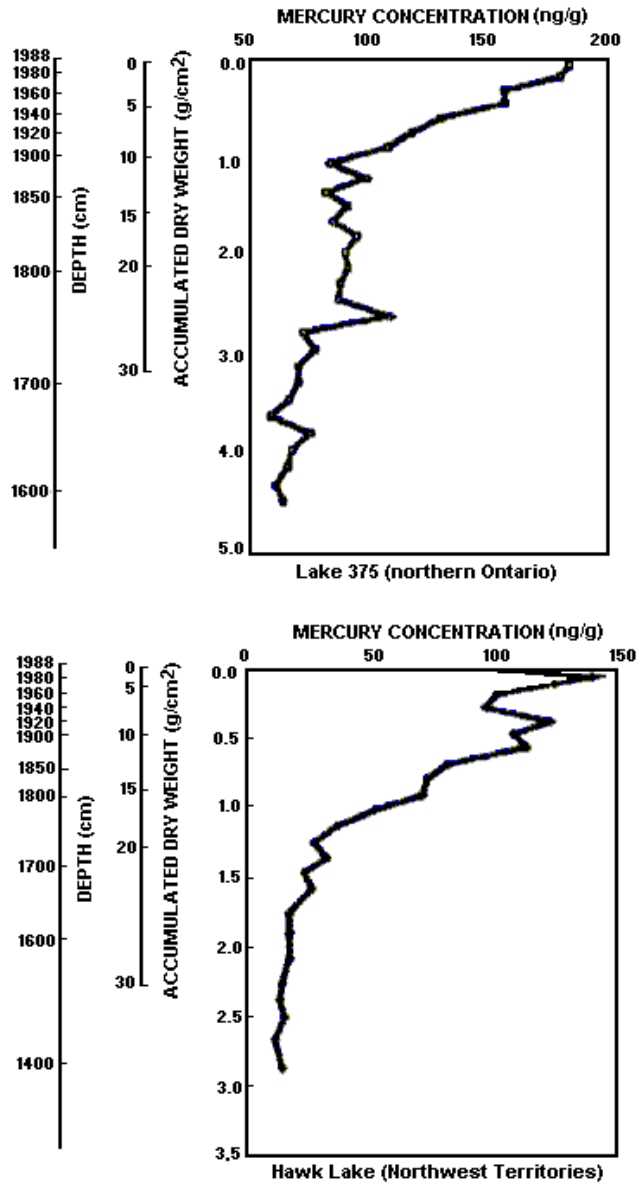


Table 4. Statistics pertaining to the number of long range transport events recorded over all verification stations over a year.

Source region	Median	75th percentile	Maximum
Asia	38	52	61
North America	11	14	25
Russia	20	24	33
Europe	1	5	27

Durnford et al. Atmos Chem Phys 10:6063-6086, 2010

Mercury in sediment slices from two northern lakes



Note: Dates earlier than 1850 are extrapolations.

Source: Lockhart et al. (1993).

Increasing Contaminant Burdens in an Arctic Fish, Burbot (*Lota lota*), in a Warming Climate

J. CARRIE,[†] F. WANG,[†,‡] H. SANEI,[§]
R. W. MACDONALD,[†,∥]
P. M. OUTRIDGE,[†,⊥] AND
G. A. STERN*[,†,▽]

Environ. Sci. Technol. **2010**, *44*, 316–322

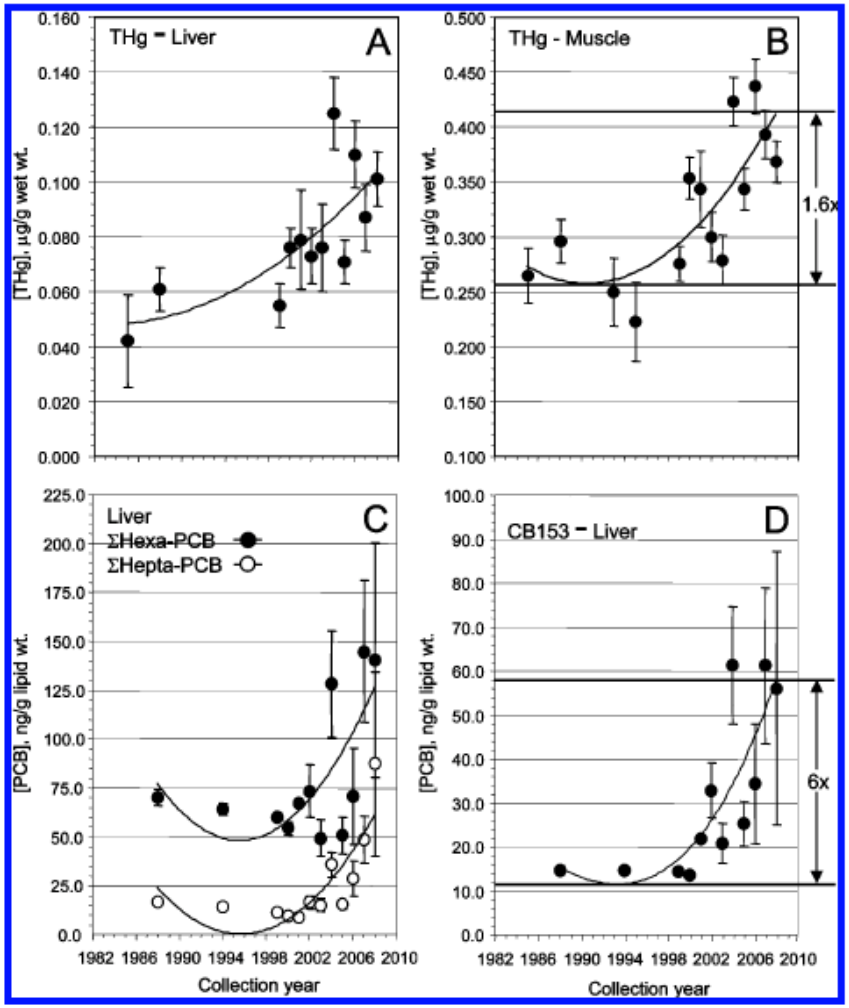


FIGURE 2. Mean (±1 SE) contaminant concentrations in Mackenzie River burbot: (A) liver HgT, (B) muscle HgT, (C) sum of hexa-hepta-PCB congeners, (D) CB 153.

Journal of Ethnobiology 26(2): 000–000 Fall/Winter 2006

RECONSTRUCTING HISTORICAL MERCURY EXPOSURE FROM BELUGA WHALE CONSUMPTION AMONG INUIT IN THE MACKENZIE DELTA

APRIL KINGHORN,[a] MURRAY HUMPHRIES,[b] PETER OUTRIDGE[c] and HING MAN CHAN[d]

TABLE 1.—Estimated Hg concentrations in three tissues of historic and modern beluga expressed per unit dry weight (dw) or wet weight (ww). For the historic sample, mean, minimum, and maximum Hg estimates are based on Hg concentrations measured in beluga teeth dated from 1450 to 1650 AD (Outridge et al. 2002). Modern samples are from beluga harvested in the Mackenzie delta in 1993 (Outridge et al. 2002).

Population	Measurement	Animal age (years)	Tooth Hg (ng/g dw)	Muscle Hg (µg/g ww)	Muktuk Hg (µg/g ww)
Historic	min	2.00	1.61	0.45	0.31
	max	26.50	19.7	0.60	0.41
	mean	**8.14**	**5.00**	**0.46**	**0.32**
Modern	min	6.50	—	0.56	0.28
	max	26.00	—	3.52	2.68
	mean	**15.78**	—	**1.75**	**1.19**

A protester carries a sign at Wednesday's downtown march by residents of the the Grassy Narrows First Nation calling on Queen's Park to acknowledge the long-term health effects of mercury contamination.

BRENDAN KENNEDY/TORONTO STAR

2. Basic concept of toxicology and risk assessment

Toxicology

The study how chemicals alter the structure and response (function) in living organisms

What is not a poison?

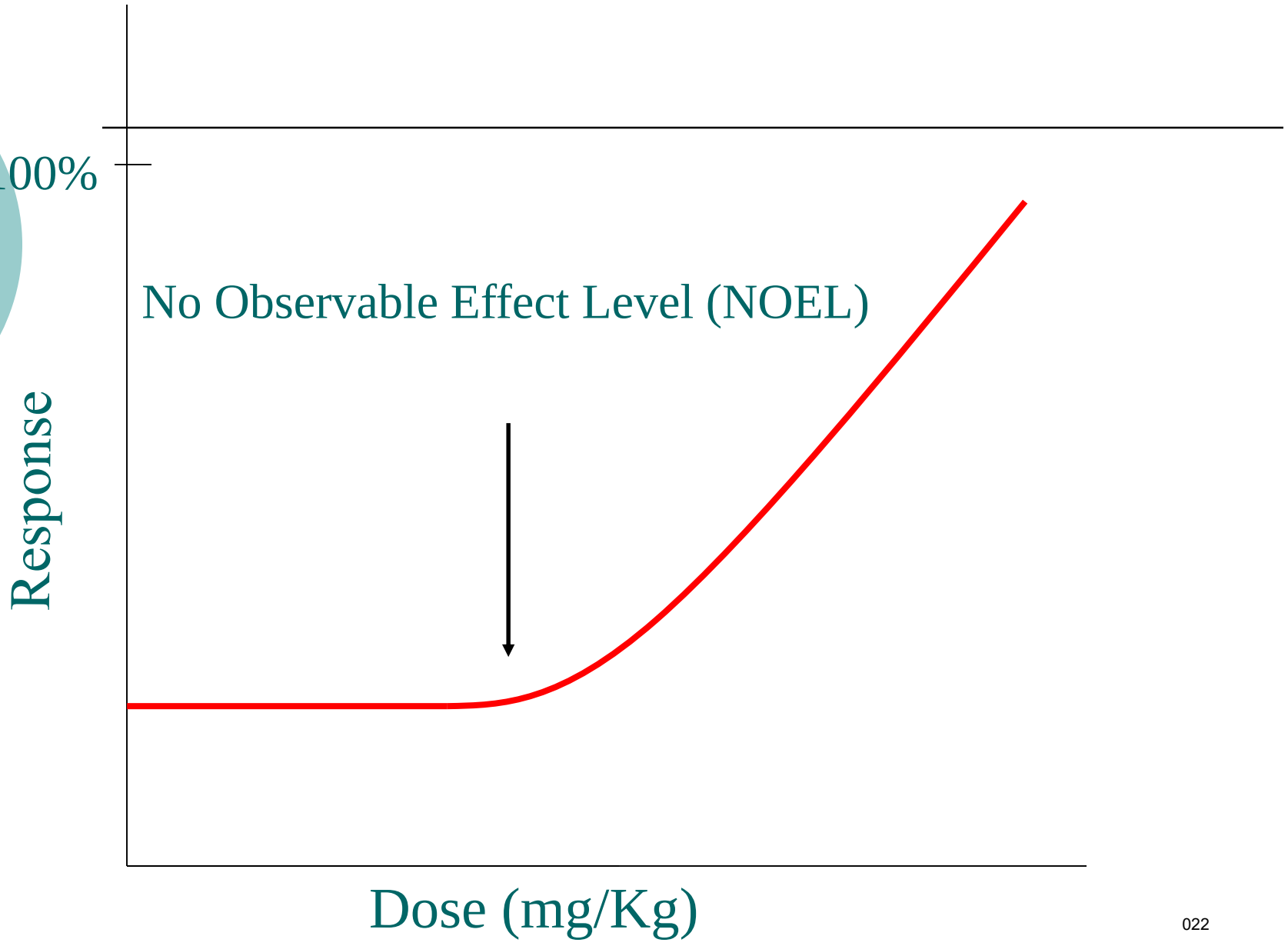
All things are poisons, and nothing is without toxicity. Only the *dose* permits anything not to be poisonous.

Paracelsus (1493-1541)

Valid Endpoints

Biological effects:

- **Threshold**
  - **for a given adverse health effect, there is a level (concentration, body burden) below which no effect can be detected**


100%
No Observable Effect Level (NOEL)
Response
Dose (mg/Kg)

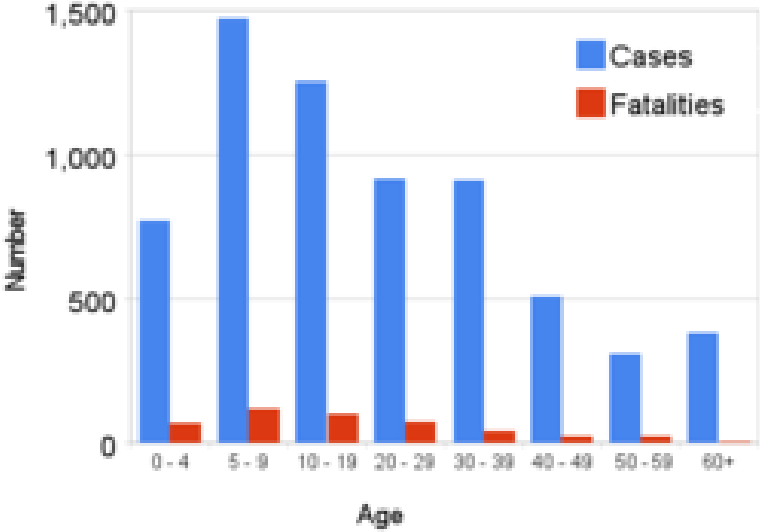
NOEL & TRV, TDI, ADI

- WHO/FAO established NOEL in 1983
- Highest dose that produce no observable effect in the most sensitive species
- LOEL - lowest dose that produce observable effect
- Animal data versus human data
- Safety factor

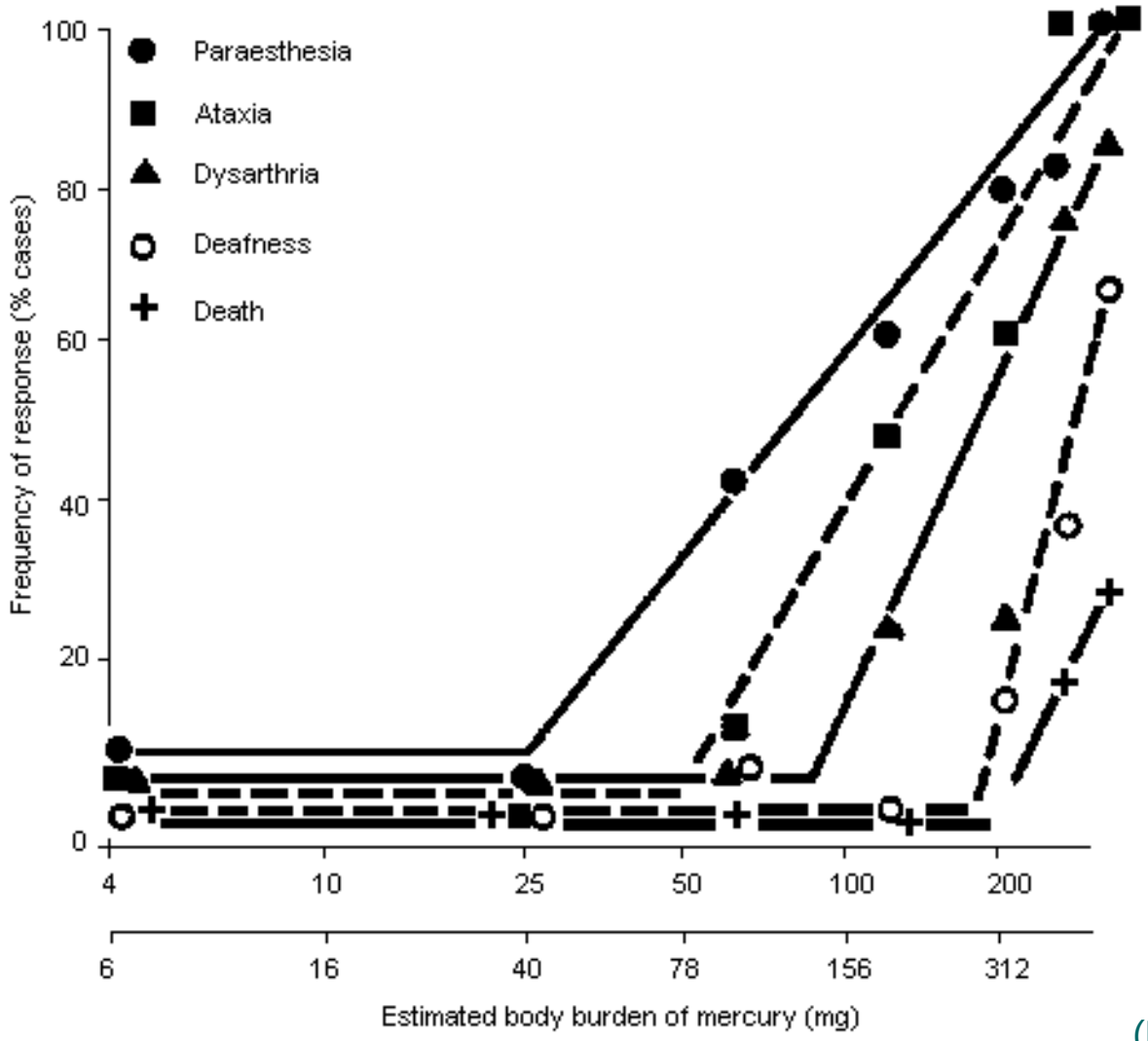
Factors affecting toxicity

- Age
- Body composition
- Sex
- Genetic Factors
- Presence of pathology
- Nutritional Factors

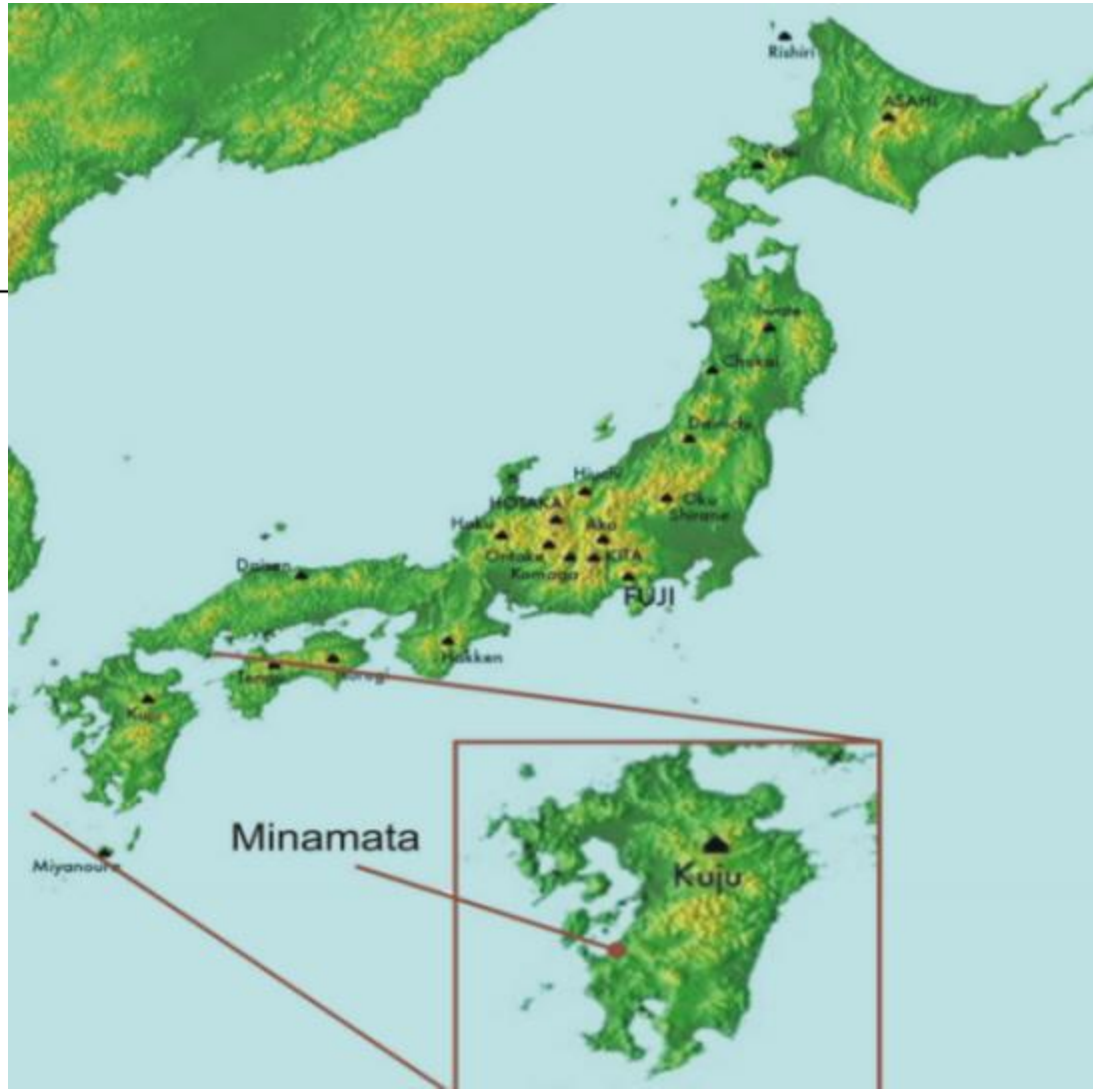
- Another case of widespread mercury poisoning occurred in rural Iraq in 1971-1972, when grain treated with a methylmercury-based fungicide was used by the rural population to make bread.



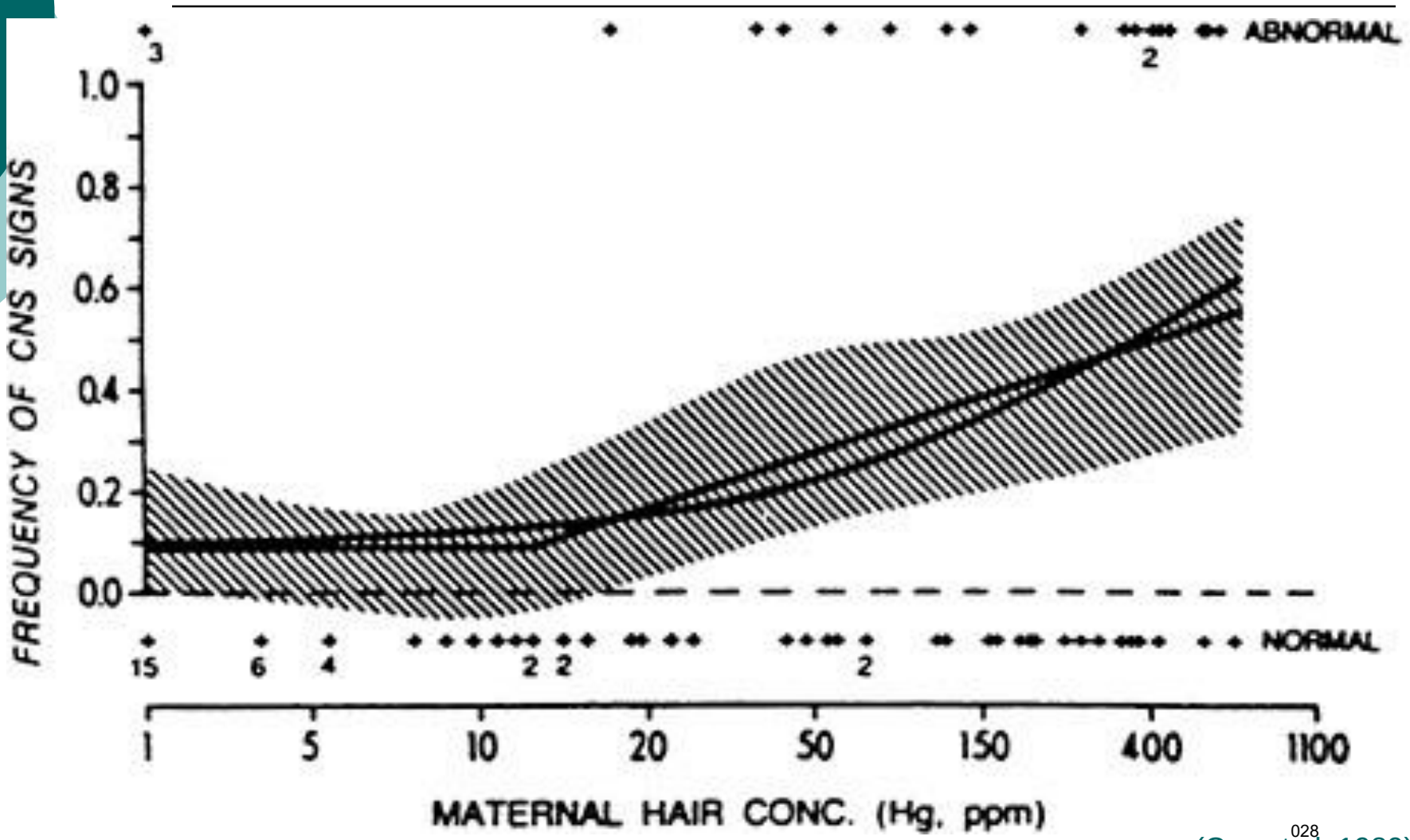
Relationship between signs/symptoms and estimated body burden of MeHg (Iraq)



(Bakir et al. 1973)


Rishiri
ASAHI
Chokai
Daisetsu
Hakusan
HOTAKA
Hakuba
Aso
Ontake
Kamagata
KITA
FUJI
Daisen
Hakkan
Kuju
Minamata
Kuju

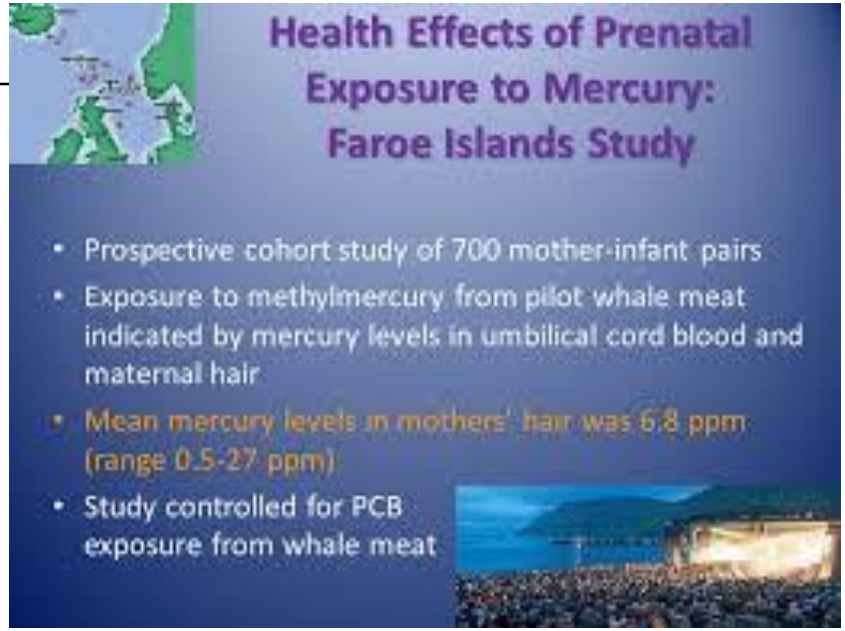
Dose-response analysis of the relationship between CNS signs and maternal-hair concentrations during gestation



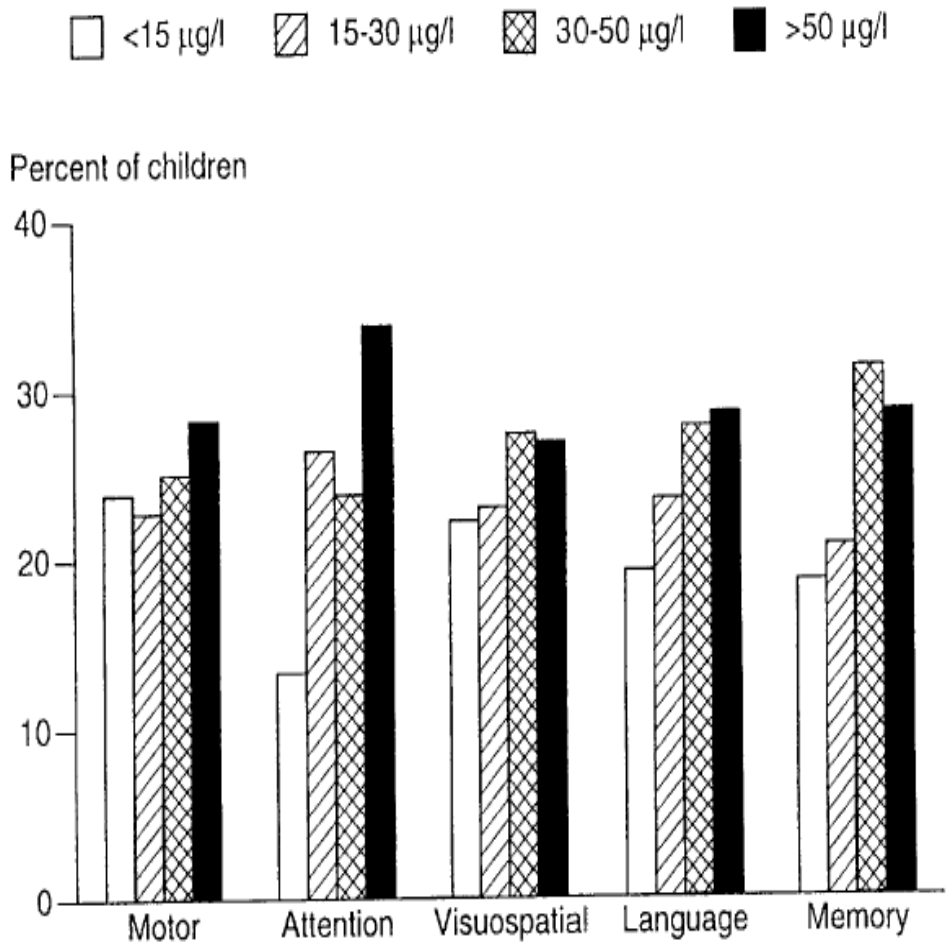
(Cox et al. 1989)

Bayley Developmental Test

Age 1 – 42 months

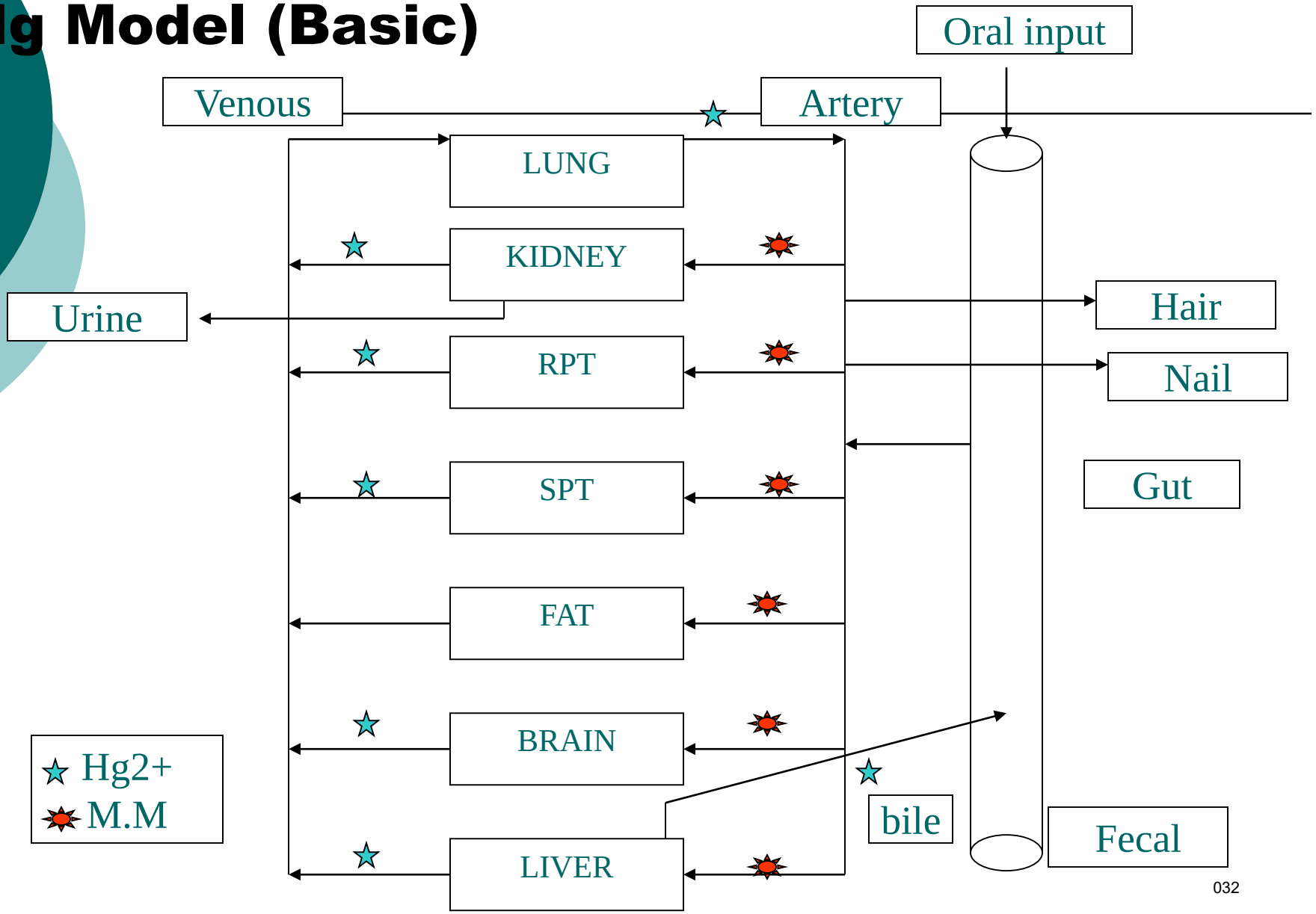

Health Effects of Prenatal Exposure to Mercury: Faroe Islands Study
Prospective cohort study of 700 mother-infant pairs
Exposure to methylmercury from pilot whale meat indicated by mercury levels in umbilical cord blood and maternal hair
Mean mercury levels in mothers' hair was 6.8 ppm (range 0.5-27 ppm)
Study controlled for PCB exposure from whale meat

Prenatal Hg Exposure levels of Faroese children with Neuropsychological Test Scores in Lowest Quartile



(Grandjean et al. 1997)

Hg Model (Basic)



World Health Organization

Evaluations of the Joint FAO/WHO Expert Committee on Food Additives (JECFA)

METHYLMERCURY

General Information

CAS number:	593-74-8
Functional Class:	Food Contaminant METALS

Evaluations

Evaluation year: 2007

Estimated exposure

Best estimate: 0.1-2 µg/kg bw/week

Toxicological study

Pivotal Study:	Epidemiology studies conducted in children from the Faroe Islands & the Seychelles (Budtz-Jorgensen et al. (1999a, 2000, 2001); United States National Research Council (2000); Rice et al. (2003), Agency for Toxic Substances and Disease Registry (1999)): Children 5.5-7 years old were assessed for neurodevelopmental endpoints, and maternal hair Hg levels were measured. An average BMDL/NOEL of 14mg/kg (14 µg/g) was derived for concentrations of mercury in maternal hair in the studies of neurodevelopmental effects, which was calculated to arise from a daily Hg intake of 1.5 µg/kg bw. The PTWI was derived by dividing this intake by a total uncertainty factor of 6.4 to give a value of 1.6 µg/kgbw.
Animal specie:	Human
Effect:	Neurotoxicity
NOAEL:	1.5 µg/kg
PTWI:	1.6 µg/kg bw
Point of departure:	BMDL: 1.5 µg/kg

- An average BMDL/NOEL of 14mg/kg (14 µg/g) was derived for concentrations of mercury in maternal hair in the studies of neurodevelopmental effects, which was calculated to arise from a daily Hg intake of 1.5 µg/kg bw. The PTWI was derived by dividing this intake by a total uncertainty factor of 6.4 to give a value of 1.6 µg/kgbw.

3. Health Canada Guideline

Health Canada Guidelines

- blood
  - <20 ppb (ug/L) normal range
  - 20-100 ppb increasing risk
  - >100 at risk
- hair
  - <6 ppm (mg/Kg or ug/g) normal range
  - 6-30 increasing risk
  - >30 ppm

COMMENTARY

Methylmercury Blood Guidance Values for Canada

Melissa Legrand, PhD,[1] Mark Feeley, MSc,[2] Constantine Tikhonov, MD, MHA,[3] Deborah Schoen, MPH,[4] Angela Li-Muller, PhD[5]

ABSTRACT

Exposure to methylmercury (MeHg) from fish and marine mammal consumption continues to present a public health concern. To date, developmental neurotoxicity is the most sensitive health outcome, forming the basis for health-risk assessments and the derivation of biomonitoring guidance values. This article summarizes existing Health Canada MeHg blood guidance values for general population and expands them to include a harmonized provisional interim blood guidance value of 8 µg/L based on the existing provisional Tolerable Daily Intake for children, pregnant women and women of childbearing age. Associated public health actions, according to age, sex, and level of exposure are recommended.

Key words: Methylmercury; biomonitoring; guidance

La traduction du résumé se trouve à la fin de l'article.

Can J Public Health 2010;101(1):28-31.

Group and age	Blood value, mg L^{-1}	Corresponding hair value, mg g^{-1}	Recommended action
Pregnant women Females birth–49 Males ≤18	<8	<2[a]	No follow-up required
Pregnant women Females birth–49 Males ≤18	8–40	2–10[a]	Repeat hair/blood test in 6 months; provide dietary advice
Pregnant women Females birth–49 Males ≤18	>40	>10[a]	Repeat hair/blood test immediately; schedule appointment with public health official
Females > 50, Males >18	<20	<6[b]	No follow-up required
Females > 50, Males >18	20–100	6–30[b]	Repeat hair/blood test in 6 months; provide dietary advice
Females and males at any age	>100	>30[b]	Repeat hair/blood test immediately; schedule appointment with public health official; refer to physician or medical toxicologist

4. WHO/FAO Risk Benefit Assessment

About 20% of the world's population derives at least one-fifth of its animal protein intake from fish

Science of the Total Environment 408 (2010) 4841–4847

Contents lists available at ScienceDirect

Science of the Total Environment

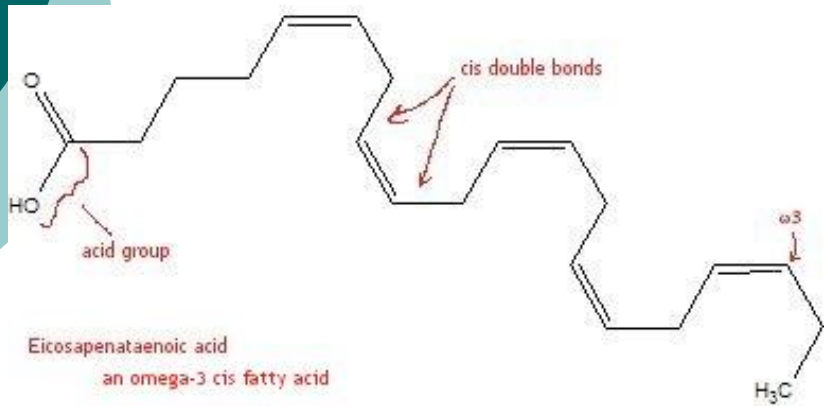
journal homepage: www.elsevier.com/locate/scitotenv

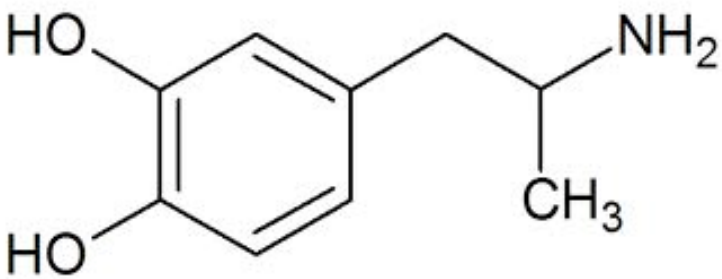
Blood total mercury and fish consumption in the Korean general population in KNHANES III, 2005

Nam-Soo Kim, Byung-Kook Lee *

27.7% of women of child bearing age (20-49 y) had Hg conc higher than the US EPA reference dose

N-3 Polyunsaturated Fatty Acids (PUFAs)





Eicosapentaenoic acid (EPA)

Docosahexaenoic acid (DHA)

Two populations at risk

- Women with high mercury intake
- Women with insufficient intake of n-3 PUFAs

To promote intake of fish types low in mercury and high in n-3 PUFA!

The Seafood Dilemma:

Health Benefits vs. Biological and Chemical Contaminants

What and how do we communicate?

Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption

Food and Agriculture Organization of the United Nations

World Health Organization

Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption

Executive Summary

Key messages

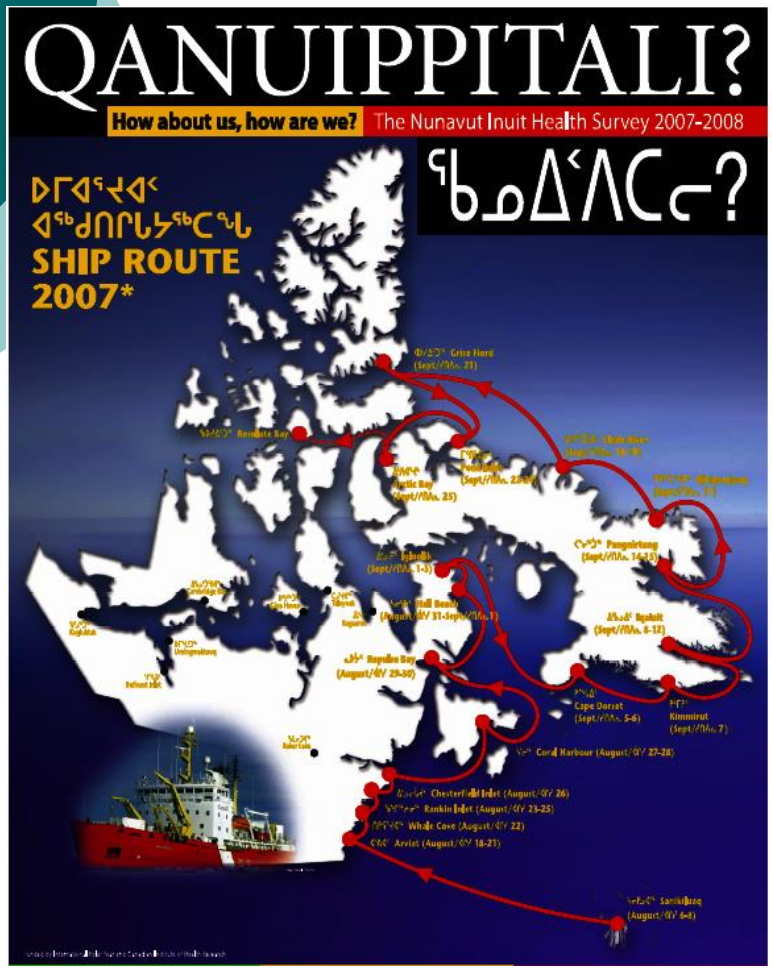
- The committee finds the evidence convincing that maternal fish consumption significantly contributes to optimal neurodevelopment in their offspring.
- Optimal health benefits of fish consumption can be achieved by maximizing LC-PUFA intake and minimizing contaminant intake.
- Fatty fish has higher levels of LC-PUFA.
- Contaminants (e.g. DLCs and MeHg) can have large regional difference. Therefore, it is critical that regional authorities have information on contaminants in fish from their region.
- Because contaminants and LC-PUFA concentrations differ in different fish species, the choice of fish species consumption is therefore important in determining the optimal benefits.
- In most cases, one to two servings per week of fish, the benefits will outweigh the risks.
- Neurodevelopmental benefits of fish consumption are reduced by MeHg contamination , and reducing MeHg contamination in fish would result in even greater neurodevelopmental benefits of fish consumption

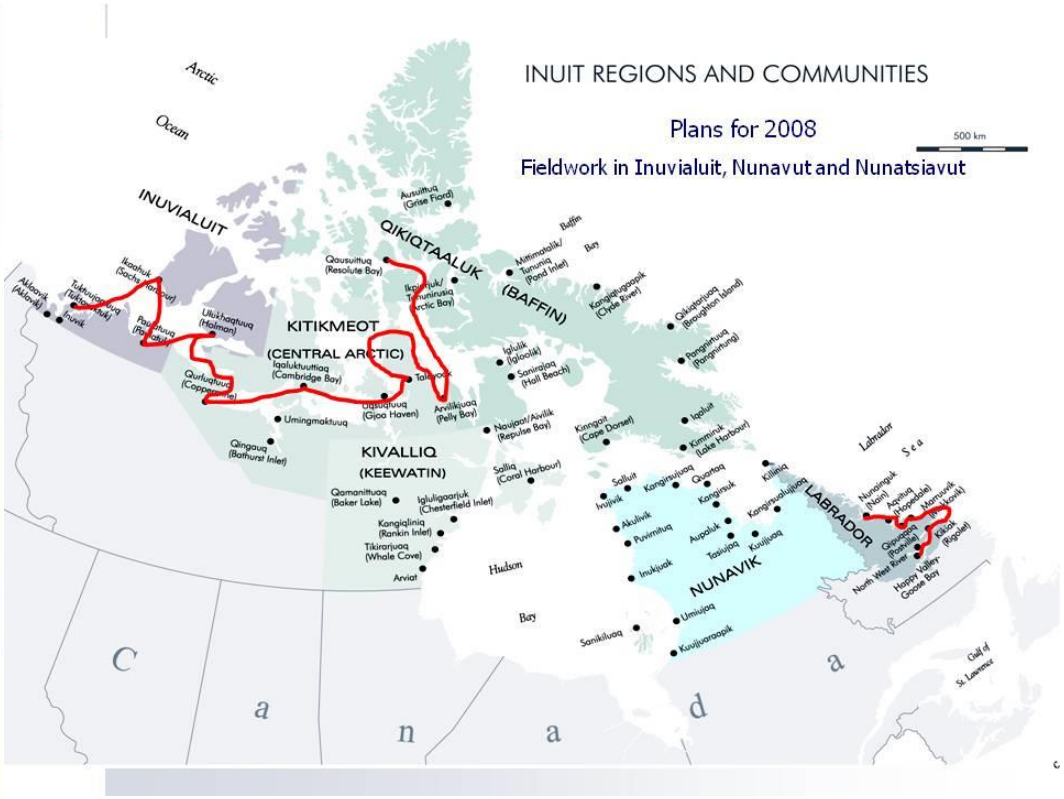
5. Results of our previous studies

Inuit Health Survey

Canadian Icebreaker: Amundsen

Inuit Health Survey 2007 and 2008





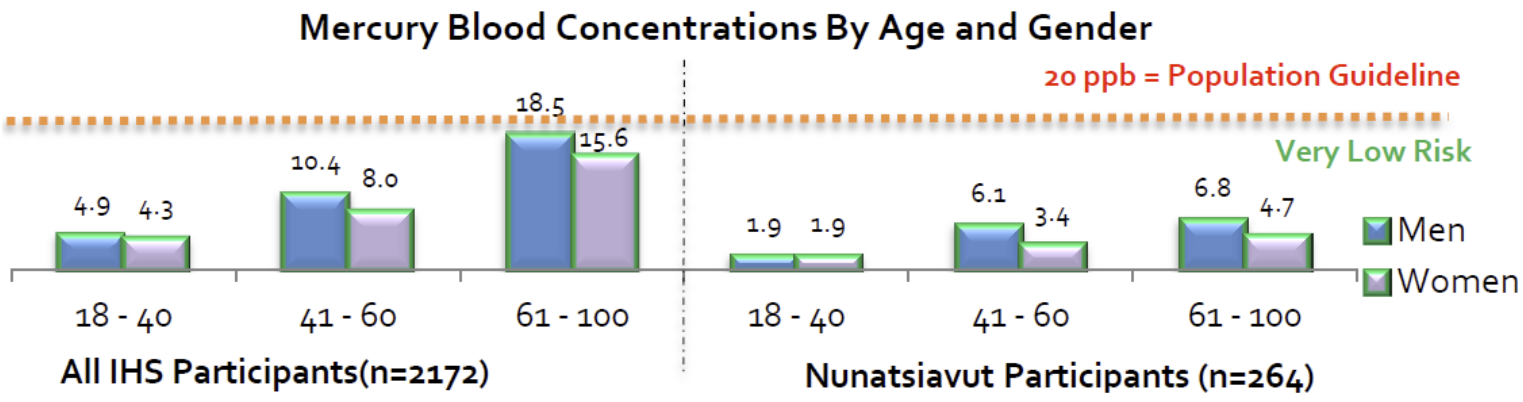
34 communities participated

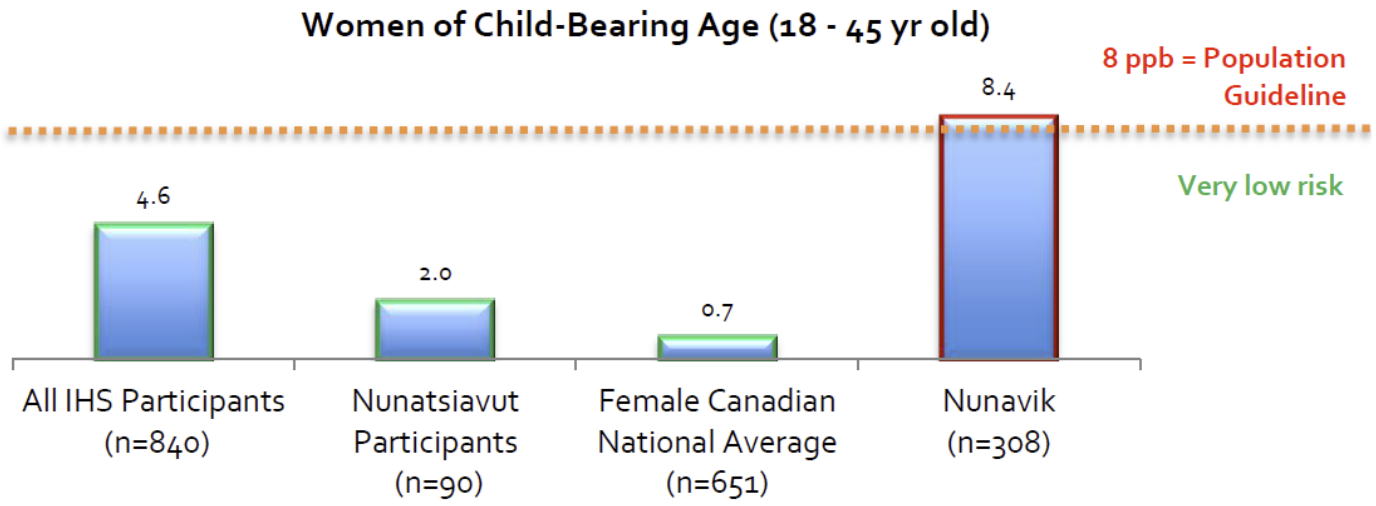
2200 participants

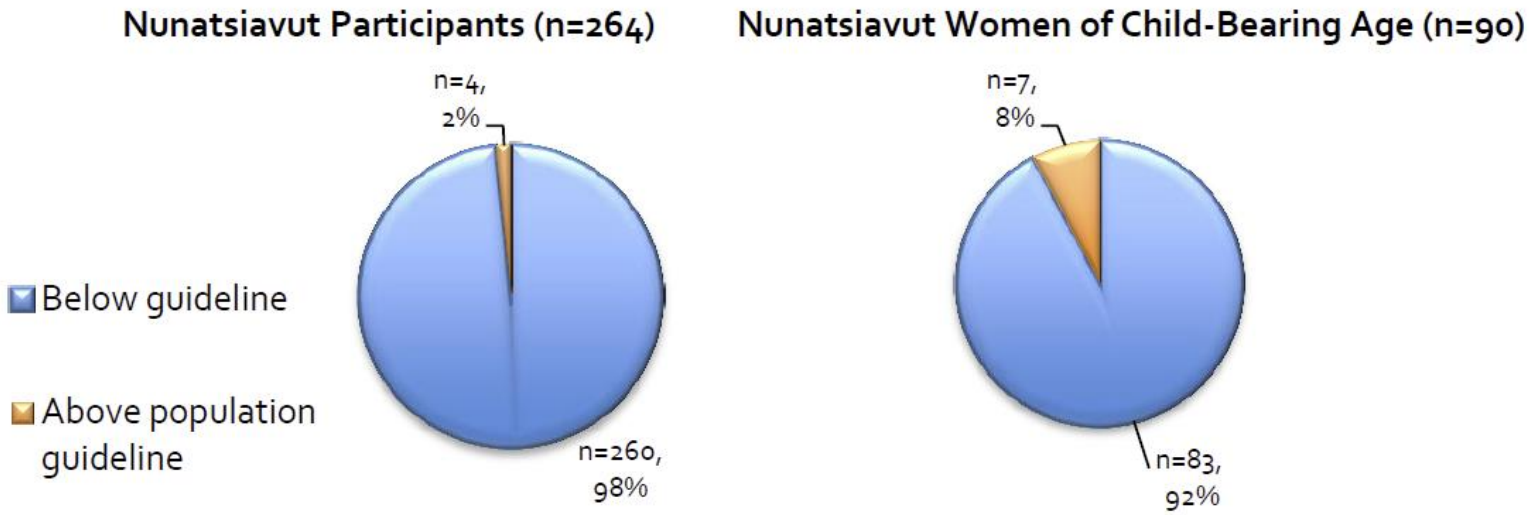
Nunatsiavut

- A total of 239 households and 310 individuals from Nain, Hopedale, Postville, Makkovik, and Rigolet participated in the survey

	Age		Gender	
	<40 yr	≥40 yr	Men	Women
Number of participants	113	197	108	202


Mercury Blood Concentrations By Age and Gender
20 ppb = Population Guideline
Very Low Risk
4.9
4.3
10.4
8.0
18.5
15.6
1.9
1.9
6.1
3.4
6.8
4.7
Men
Women
18 - 40
41 - 60
61 - 100
18 - 40
41 - 60
61 - 100
All IHS Participants(n=2172)
Nunatsiavut Participants (n=264)


Women of Child-Bearing Age (18 - 45 yr old)
8 ppb = Population Guideline
Very low risk
4.6
2.0
0.7
8.4
All IHS Participants (n=840)
Nunatsiavut Participants (n=90)
Female Canadian National Average (n=651)
Nunavik (n=308)

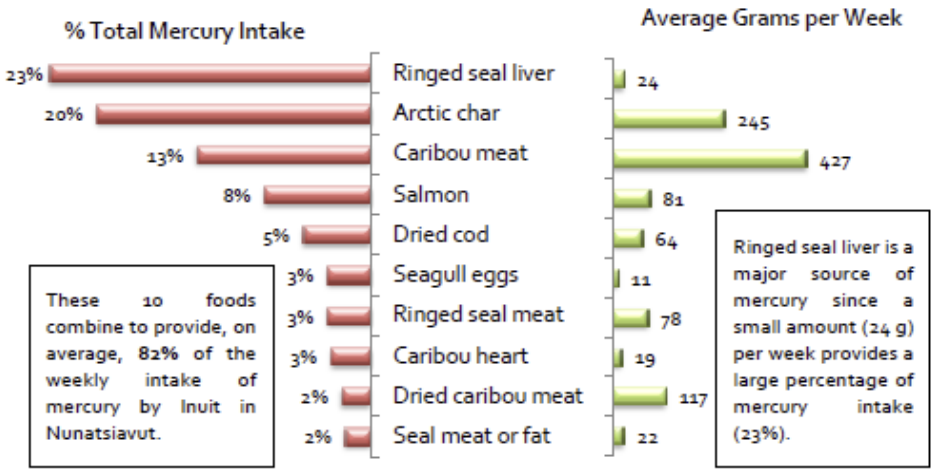

Nunatsiavut Participants (n=264)
Nunatsiavut Women of Child-Bearing Age (n=90)
Below guideline
Above population guideline
n=4, 2%
n=260, 98%
n=7, 8%
n=83, 92%

Major Country Food Sources of Mercury Intake

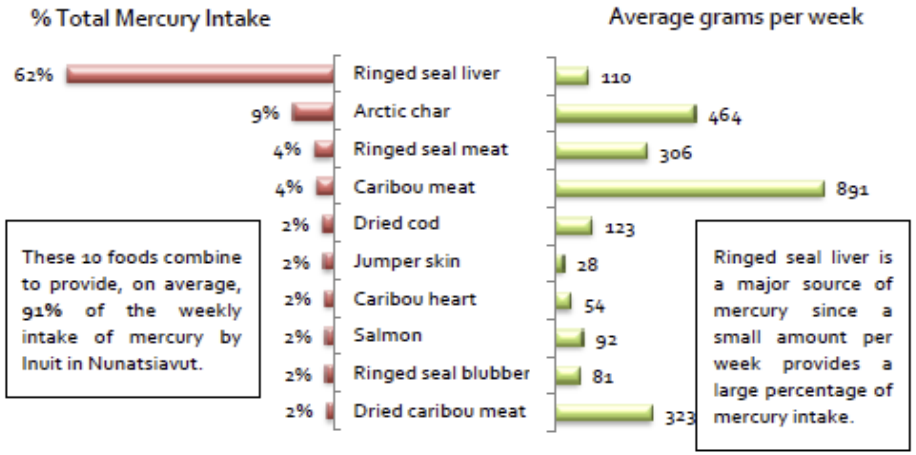
This column shows on average, how much each country food contributed to mercury intake.

This column shows on average, how much of each country food was eaten by each participant.

All Nunatsiavut Participants (n=264)



Nunatsiavut Participants with Mercury Levels Above the Intake Guideline



A Section 508–conformant HTML version of this arti
is available at http://dx.doi.org/10.1289/ehp.14085

Research | Children's Health

Relation of Prenatal Methylmercury Exposure from Environmental Sources to Childhood IQ

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Environmental Research ■ (■■■■) ■■■–■■■

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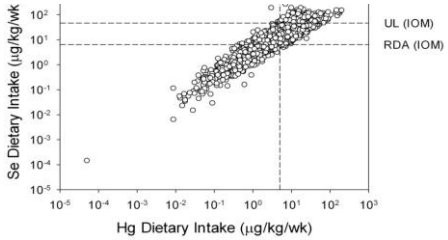
Mercury diminishes the cardiovascular protective effect of omega-3 polyunsaturated fatty acids in the modern diet of Inuit in Canada ☆

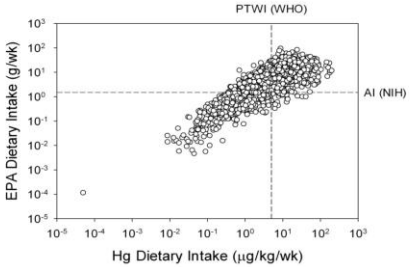
Xue Feng Hu [a,b], Brian D. Laird [c], Hing Man Chan [a,b,*]

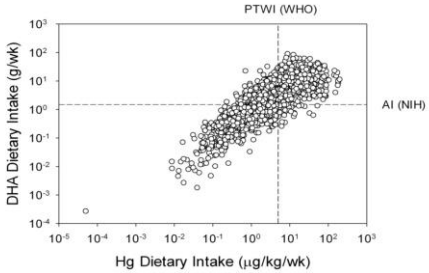
The Journal of Nutrition
Community and International Nutrition

Dietary Advice on Inuit Traditional Food Use Needs to Balance Benefits and Risks of Mercury, Selenium, and n3 Fatty Acids[1–3]

Brian D. Laird,[4,6] Alexey B. Goncharov,[4] Grace M. Egeland,[5] and Hing Man Chan[4,6]*







Laird et al. 2013

Study says ringed seal liver dangerous for pregnant women

Nunavut's health department says high mercury levels affect development in newborns

CBC News Posted: Jun 28, 2012 6:05 PM CT | Last Updated: Jun 28, 2012 8:24 PM CT

Dr. Laurie Chan, a toxicologist with the University of Ottawa, says the contaminants in ringed seal liver come from pollution in the atmosphere. (Meghan Roberts/CBC)

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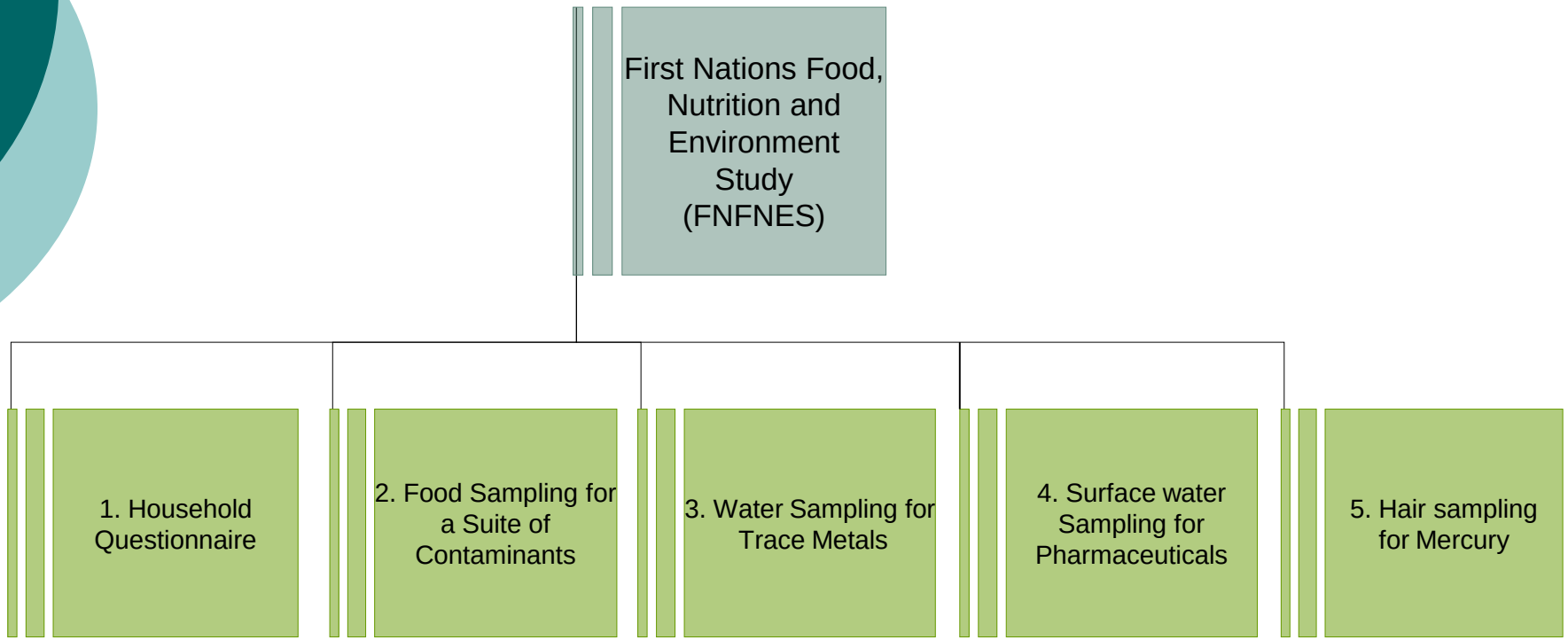
First Nations Food, Nutrition and Environment Study

Atlantic Region

Funding for this study is provided by Health Canada.

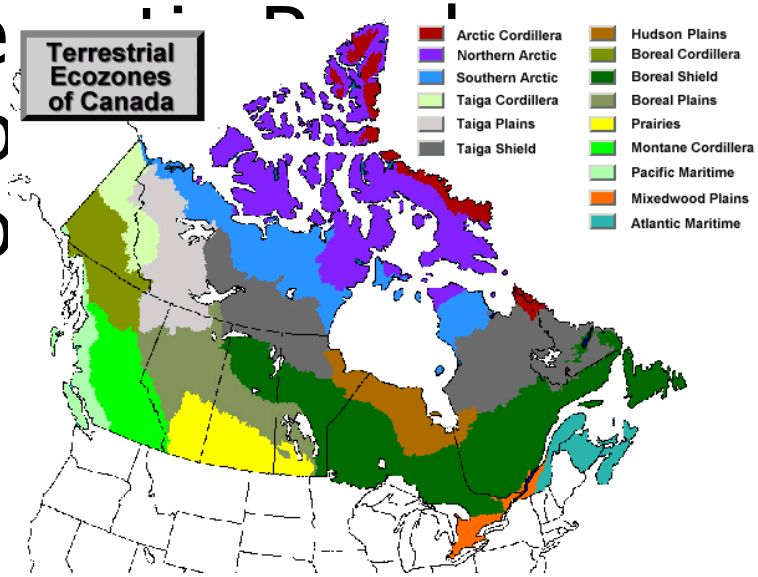
The information and opinions expressed in this presentation are those of the authors/researchers and do not necessarily reflect the official views of Health Canada.

First Nations Food, Nutrition and Environment Study

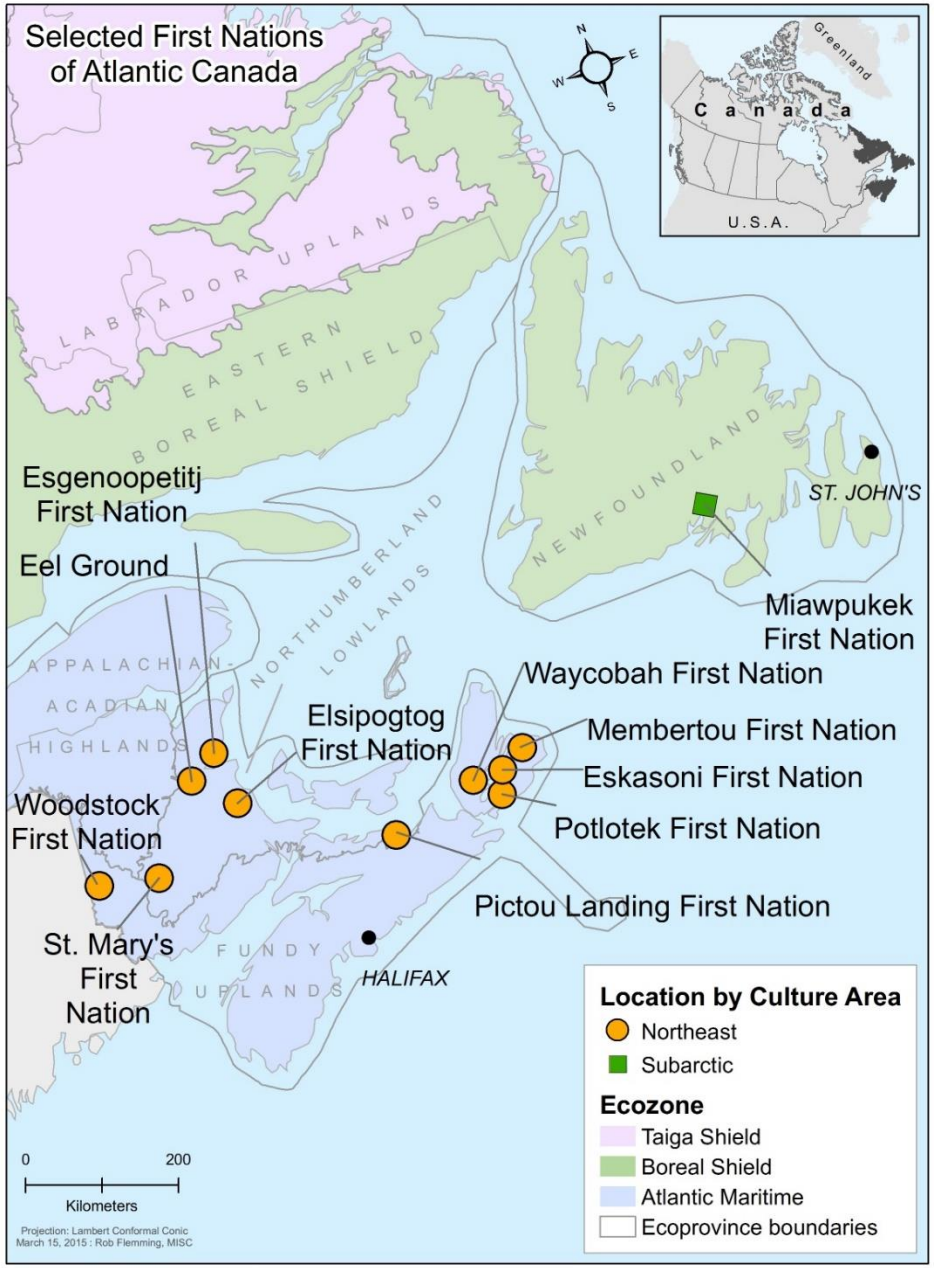


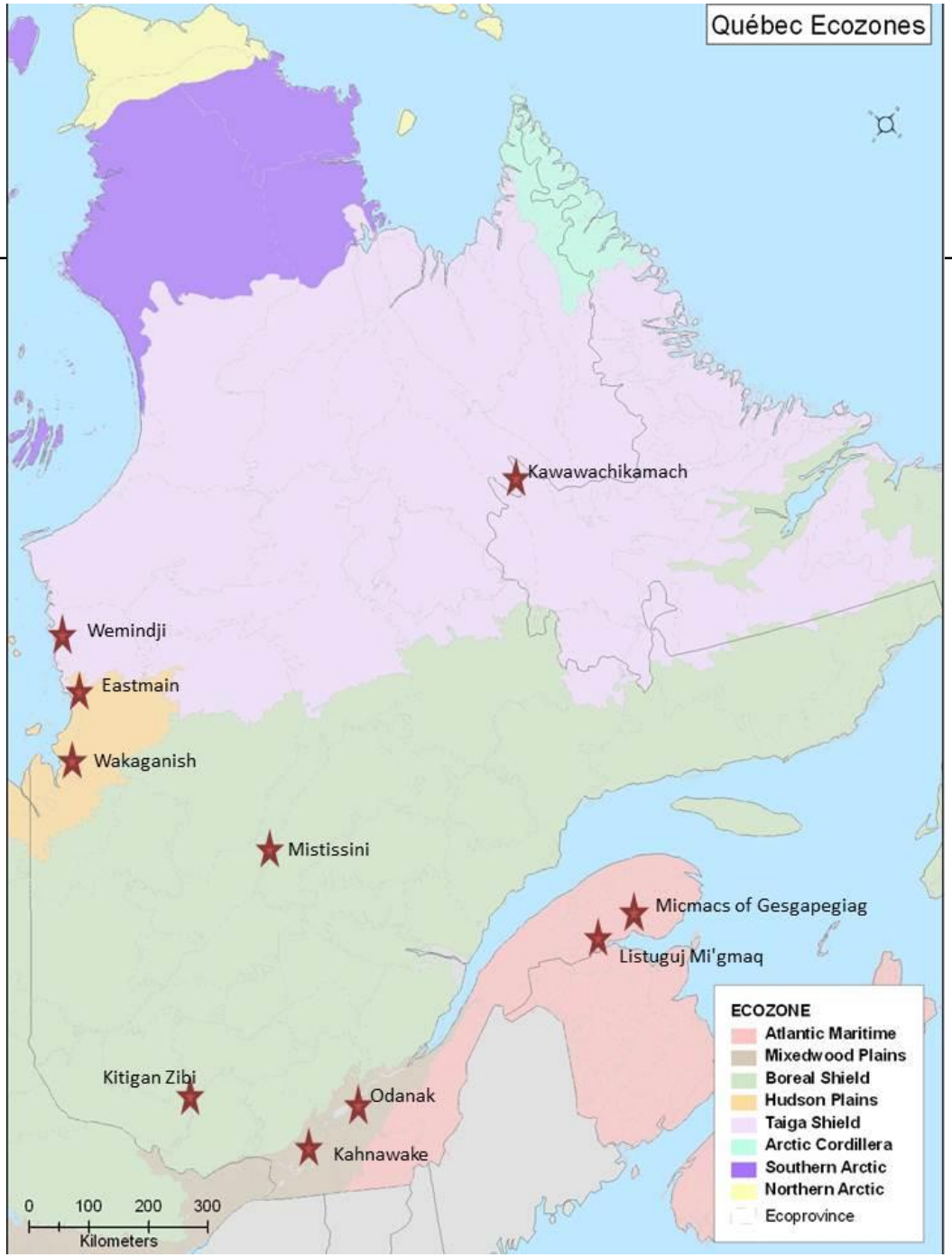
First Nations Food, Nutrition and Environment Study

- 100 communities from 2008-2018
- ~8 - 12 communities per year
- Syste
  Samp
  ecozo



2014 Partner First Nations

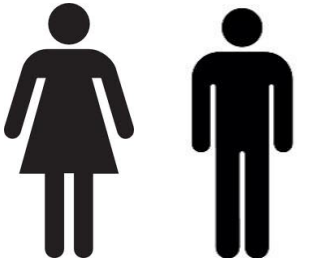




Quebec Ecozones

Who participated?

1025 adults in the Atlantic



670 355

Average age of **42** for **females** and **40** for **males.**

The participation rate in the Atlantic was **90%** (1025/1139 eligible households).

Traditional Food and Diet Quality

On days when Traditional Food is eaten	On days when only market food is eaten
The intake of many nutrients is higher including: Protein Zinc Iron Vitamin D Vitamin B_{12} Vitamin B_6	Intake of saturated fat is higher Intake of sodium is higher

Food Security

In the Atlantic, both **moderately food insecure (22%)** and **severely food insecure households (9%)** are common and much higher than the Canadian average

In the rest of FNFNES regions: in BC 41% are food insecure; 38% in MB; 29% in ON;
47% in AB compared to 8% in rest of Canada

Mercury Levels in Hair

- 632 hair samples were collected from adults.
- Mercury levels were within Health Canada's guideline normal acceptable range for all participants.

Thank you

For more information, email
fnfnes@uottawa.ca
Or phone 613-562-5800 ext. 7214
Please visit our website at www.fnfnes.ca

6. Local Monitoring Results

Golder Biomonitoring Results

Table 5: Summary Statistics of Total Mercury Concentrations in Hair for All Study Participants

Community	Summary Statistics of Total Mercury Concentrations in Hair (mg/kg)					
	Arithmetic Mean	Geometric Mean	Median	Standard Deviation	Minimum	Maximum
All Participants (n=293)	0.3117	0.0931	0.089	0.5993	0.004	4.34
Females						
1-4 years (n=7)	0.0673	0.0484	0.0743	0.0495	0.012	0.134
5-11 years (n=27)	0.0506	0.0274	0.0274	0.0698	0.0061	0.288
12-19 years (n=24)	0.0536	0.0251	0.0195	0.0686	0.004	0.257
20+ years (n=139)	0.2802	0.1155	0.106	0.4767	0.0041	4.12
Males						
1-4 years (n=6)	0.0674	0.0391	0.04715	0.0638	0.0098	0.146
5-11 years (n=11)	0.0374	0.0226	0.017	0.0477	0.0095	0.158
12-19 years (n=14)	0.0763	0.0409	0.0695	0.0729	0.0041	0.244
20+ years (n=65)	0.7288	0.2781	0.329	0.9346	0.008	4.34

Calder 2016 Biomonitoring Results

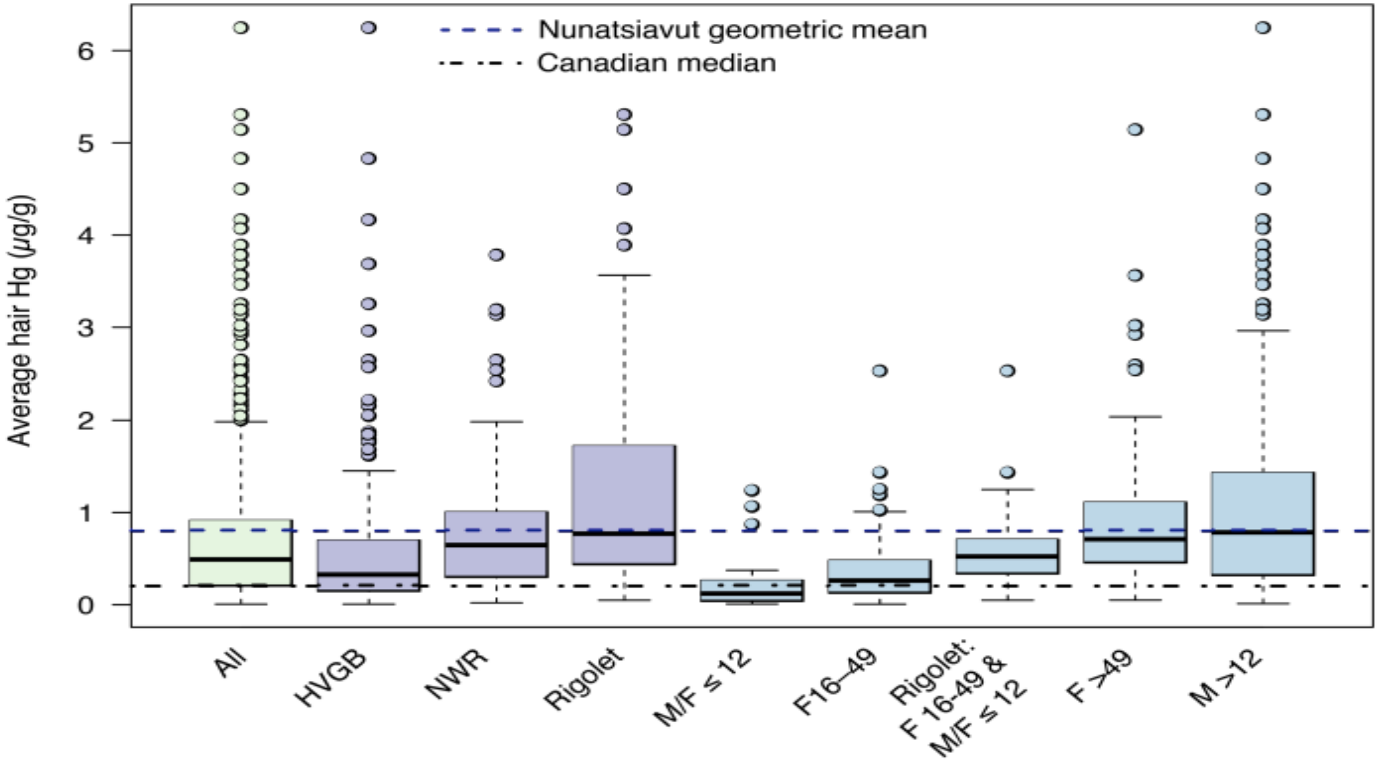


Figure S4. Measured concentrations of total Hg in hair samples from individuals in three Inuit

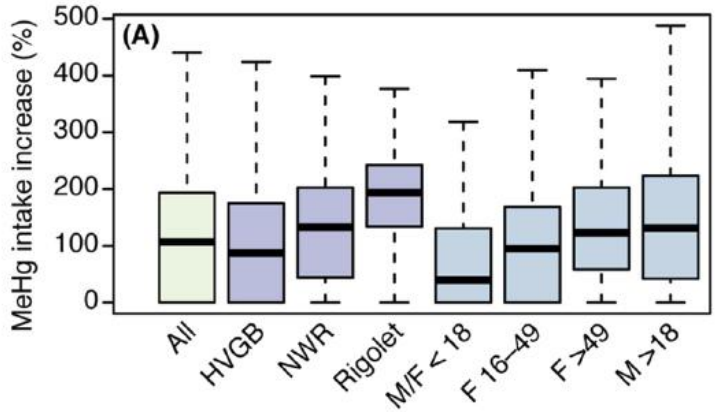
Environmental Science & Technology

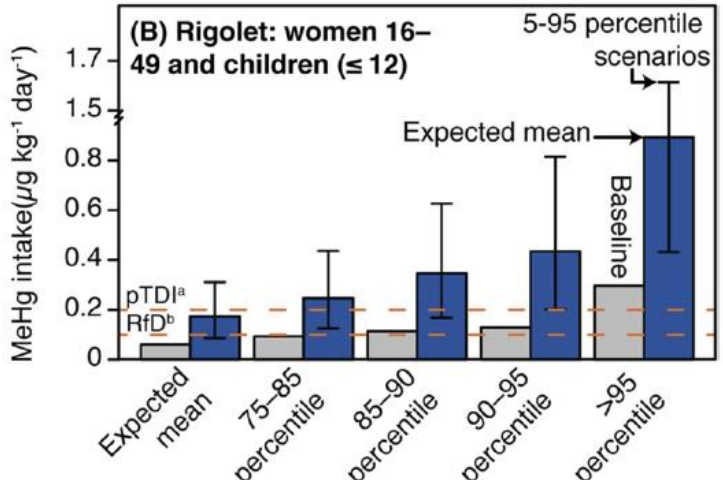
Article

pubs.acs.org/est

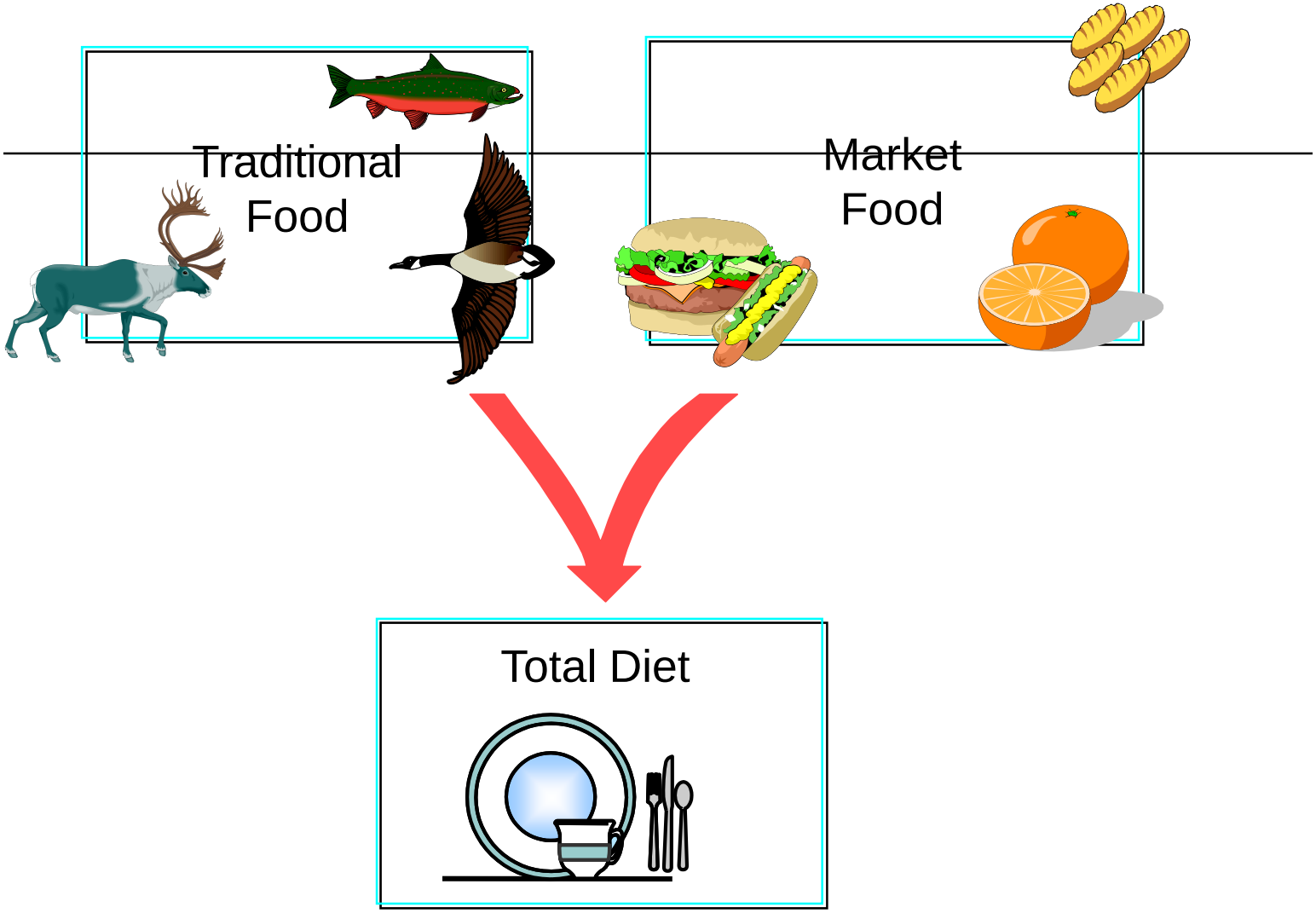
Future Impacts of Hydroelectric Power Development on Methylmercury Exposures of Canadian Indigenous Communities

Ryan S. D. Calder,[*,†,‡] Amina T. Schartup,[†,‡] Miling Li,[†,‡] Amelia P. Valberg,[†] Prentiss H. Balcom,[‡] and Elsie M. Sunderland[†,‡]



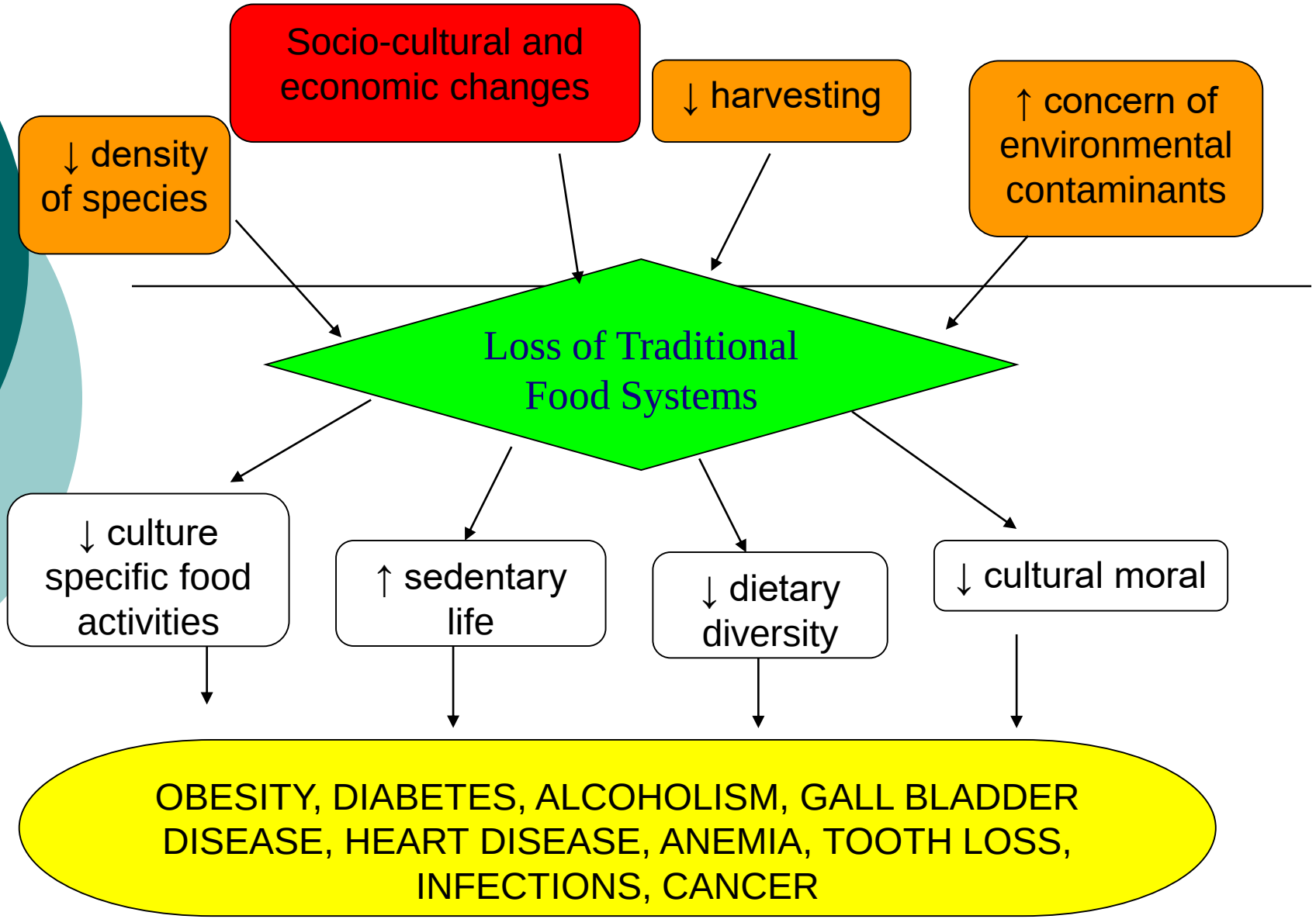


Final Note


Traditional Food
Market Food
Total Diet

Decrease availability of nutritious country foods and high cost but often poor quality of market food

Arctic char and caribou skins drying


Socio-cultural and economic changes
↓ harvesting
↑ concern of environmental contaminants
↓ density of species
Loss of Traditional Food Systems
↓ culture specific food activities
↑ sedentary life
↓ dietary diversity
↓ cultural moral
OBESITY, DIABETES, ALCOHOLISM, GALL BLADDER DISEASE, HEART DISEASE, ANEMIA, TOOTH LOSS, INFECTIONS, CANCER

Eat more fish!

- Not all fish is the same

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Balancing the benefits of n-3 polyunsaturated fatty acids and the risks of methylmercury exposure from fish consumption

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Public Health, Washington DC, US

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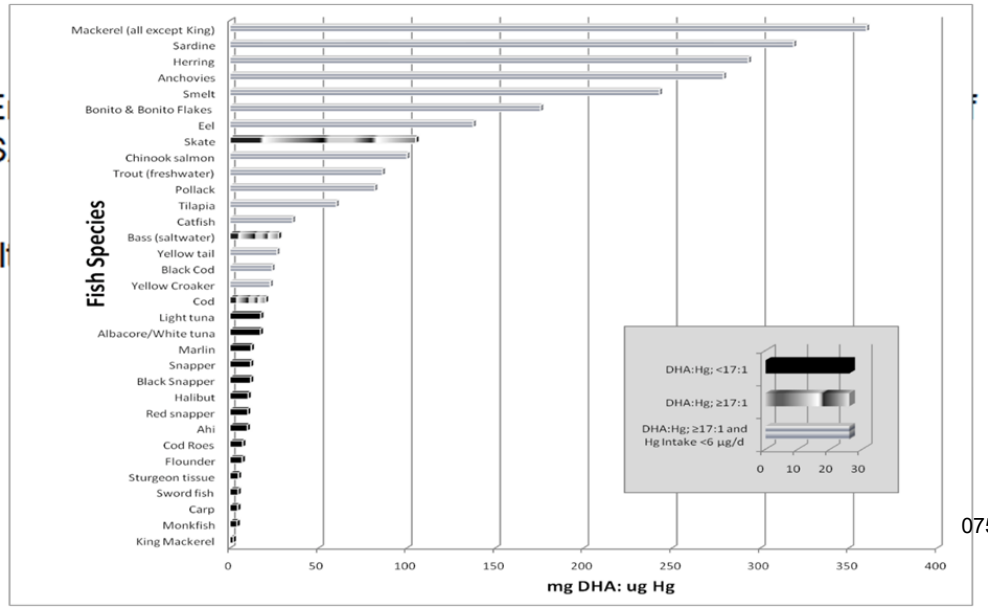
USA

Hing Man Chan



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Questions?