Methylmercury Risk Analysis at Muskrat Falls

Webinar 2: Integrated environment-human health modeling at Muskrat Falls

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Principal Investigator: EM Sunderland

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Independent Expert Advisory Committee, Newfoundland and Labrador

Recap: Nalcor studies

- Hg levels in fish
  - Statistical approaches (Harris and Hutchinson 2008)
    - Limitations: extrapolation to Labrador; are all relevant parameters captured?
  - Mechanistic (Harris et al. 2010)
    - Limitations: little chemical data available at this time; role of carbon?
- Exposure assessments (Dillon 2016; Golder 2011 & 2015; Minaskuat 2008)
  - Limitations: Population means vs. RfDs; Indigenous vs. non-indigenous; no assessment of incremental exposures or handling of high consumers
- Lake Melville excluded from study area

Recap: Harvard studies

- Goal 1: Characterize baseline Hg budget of Churchill River/Lake Melville system
  - Sources, sinks and biotic transfer of MeHg
- Goal 2: Structure available data into predictive model for post-flooding MeHg impacts
  - Water column
  - Biota
- Goal 3: Evaluate impacts for Inuit exposures
  - Baseline exposure characterization
  - Probabilistic forecast

Structure

- Goal 1: Baseline Hg budget
- Goal 2: Predictive model for flooding
  - A. Post-flooding peak in soils
  - B. Diffusion and downstream transport
  - C. Peak Hg in aquatic life
- Goal 3: Inuit exposures
  - A. Lake Melville Inuit Health Study (baseline diet and Hg exposures)
  - B. Probabilistic forecasts
- Q&A + discussion
  - (Or feel free to ask questions throughout!)

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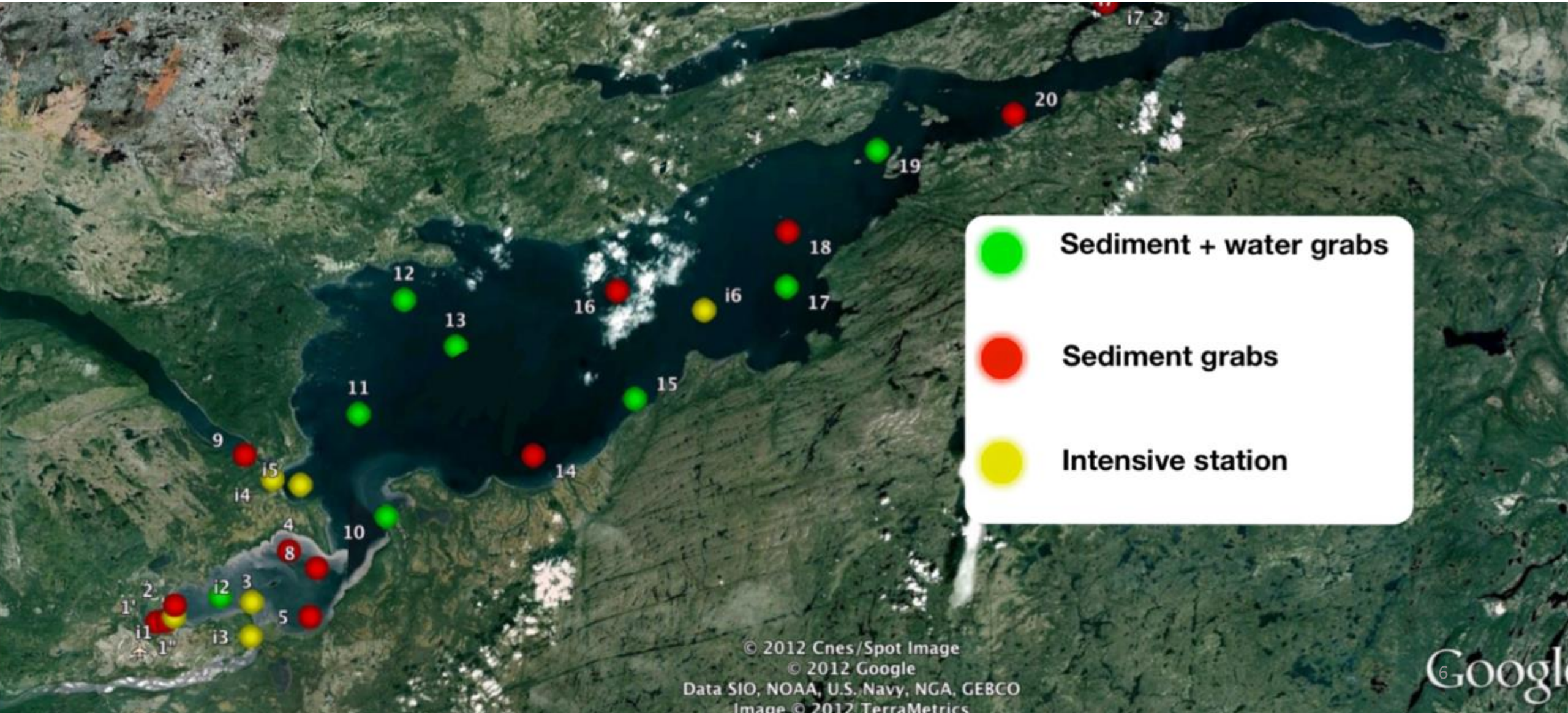
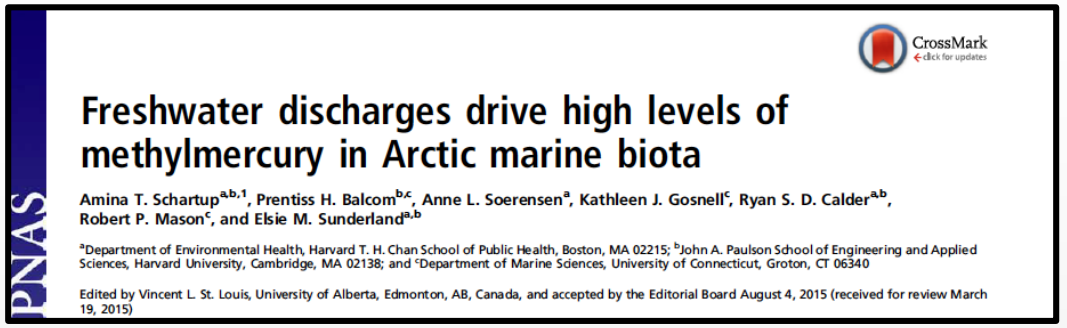
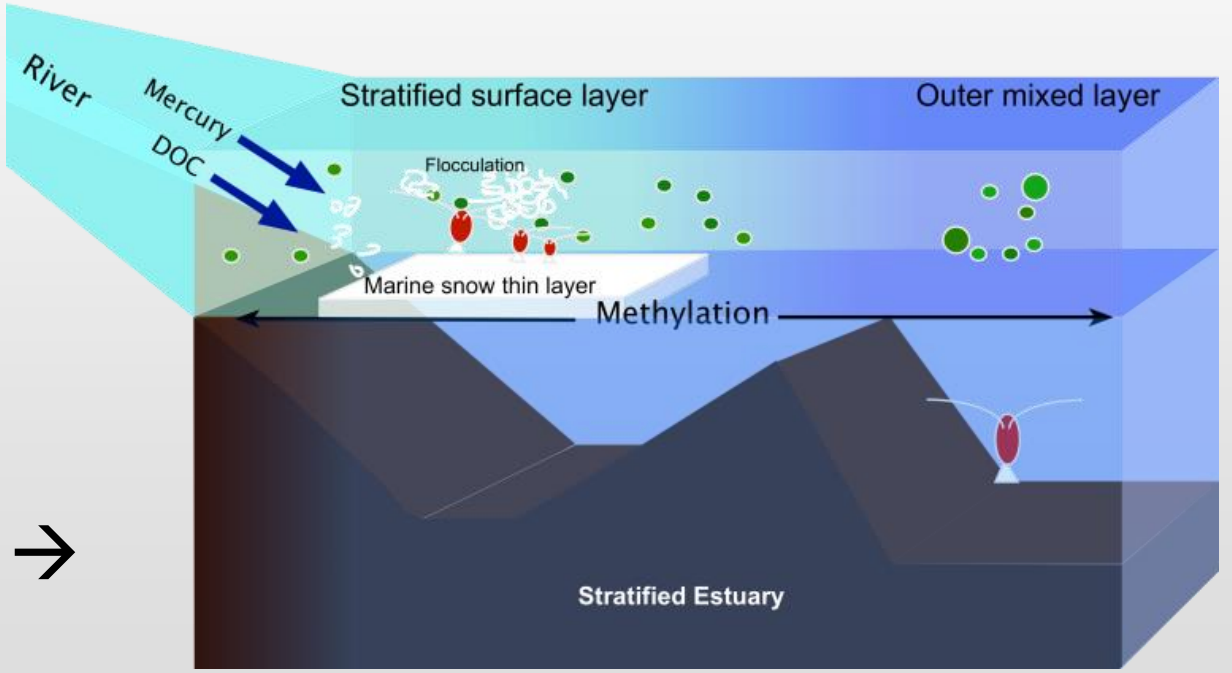
Environmental sampling in/around Lower Churchill River/Lake Melville: 2012 to present



Schartup et al. 2015

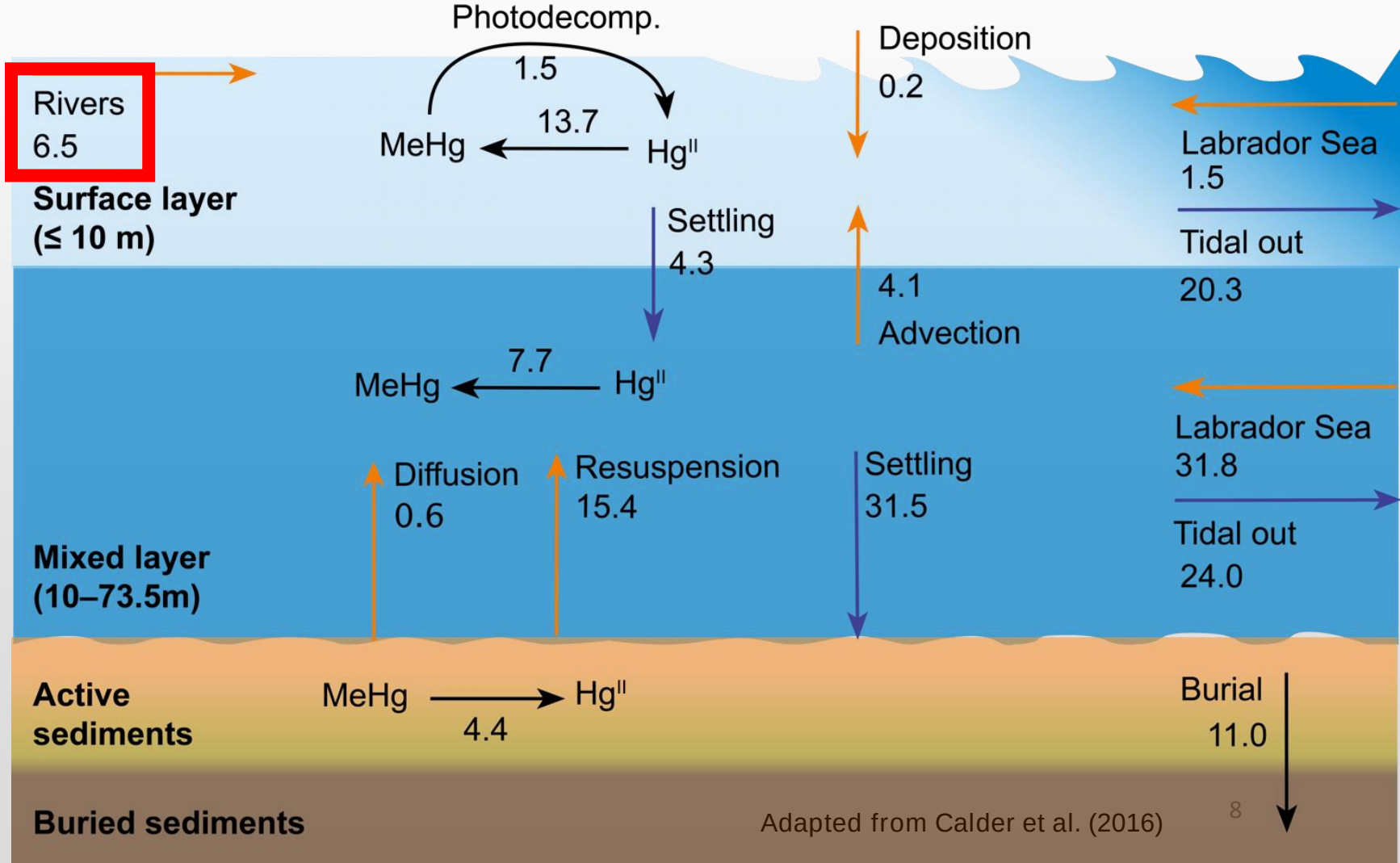
- Seasonal (Summer-Fall/Winter/Spring) 2012–14
- Hg^0, Hg^{II}, MeHg concentrations
  - Sediment
  - Water column
  - Plankton (uptake into food chain)
- Methylation rates
- Budget model for Lake Melville
- Flood experiments (short duration → low estimates)





Lake Melville Hg budget

- Stratification important for concentrating riverine inputs into plankton
- Rivers important MeHg source
- Adapted two-layer model developed for biotic forecasts (pictured; units = mol yr^{-1})



Adapted from Calder et al. (2016)

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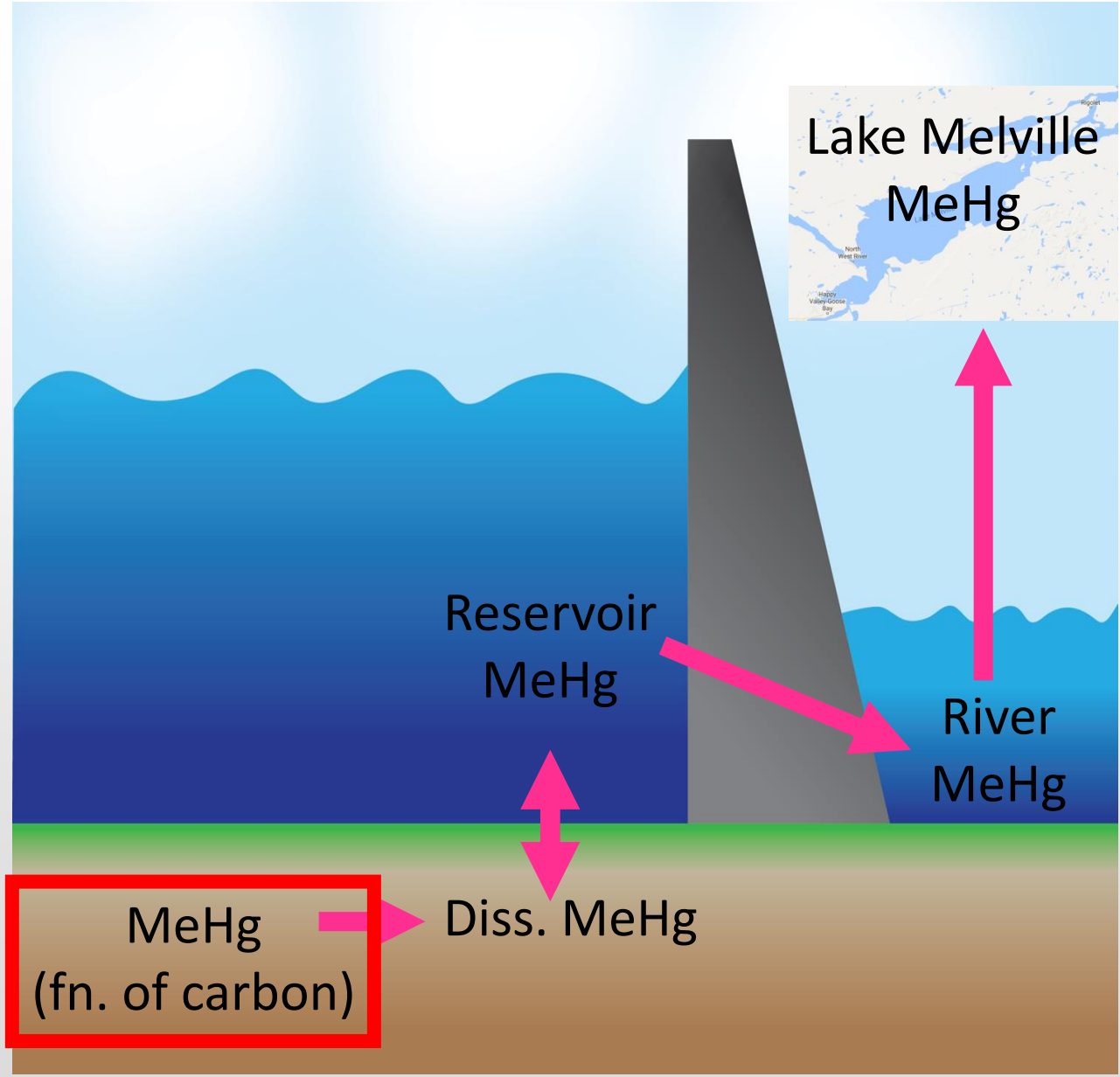
Predictive model

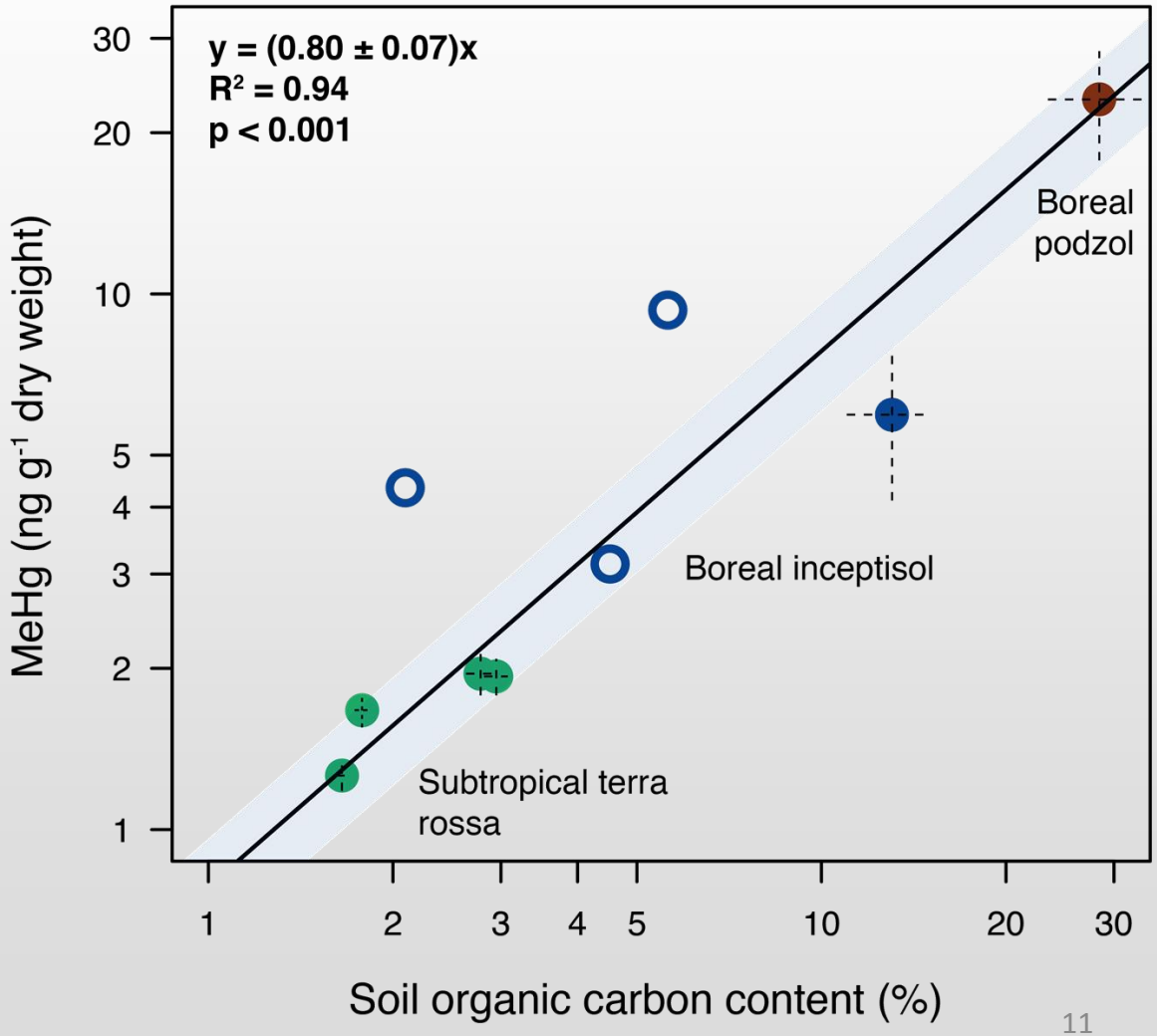
- Many factors likely to be different at Muskrat Falls vs. sites where statistical models (e.g., fish Hg vs. reservoir characteristics) have been calibrated
  - High organic carbon
  - High shear stresses
  - Interest in downstream environment
- Approach: model outcomes of interest as the product of fundamental processes and leverage all available data
  - Model validation for individual processes



Peak soil MeHg vs. organic carbon

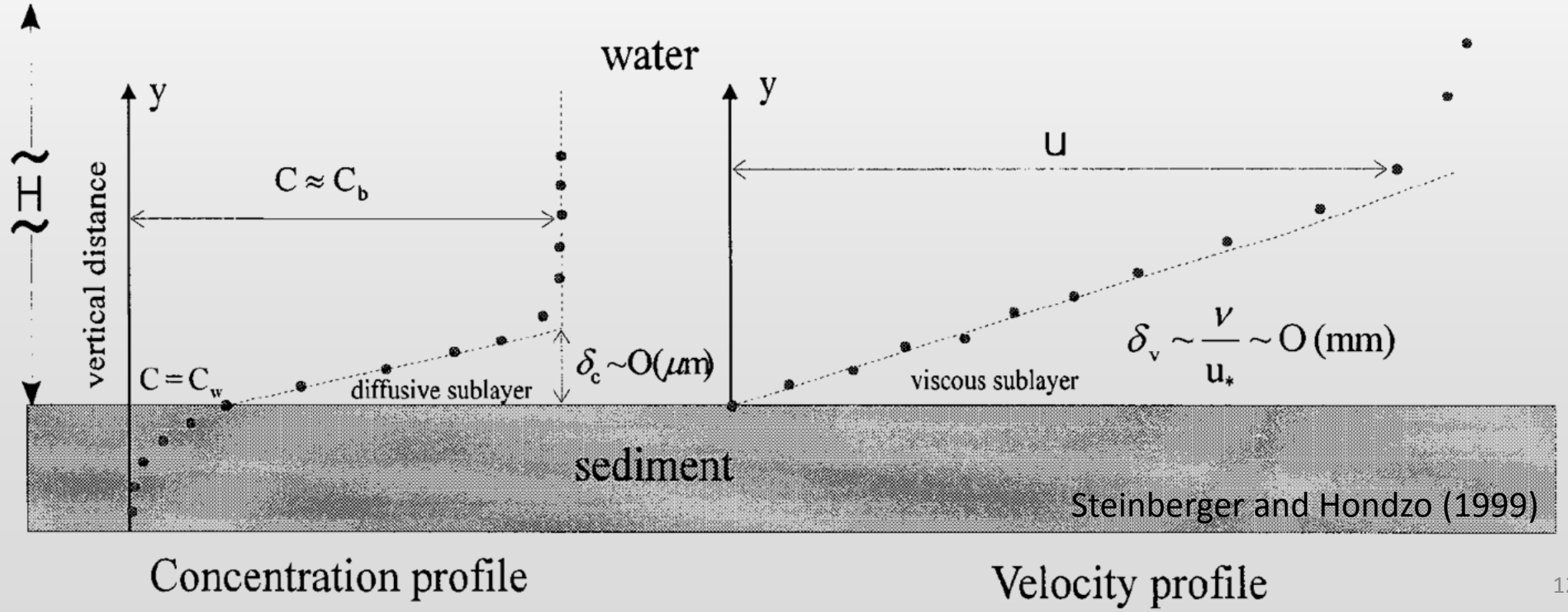
- Best predictive relationship we found: Peak MeHg vs. OC
  - Hg^{II} highly correlated with OC
- Aggregating sites → wide range of applicability
  - Clear MeHg vs. OC relationship exists *within* sites, too
- This measure is relatively free from site-specific processes that introduce noise to the data

Calder et al. (2016)



Water column diffusion mediated by site-specific variables (modeled probabilistically)

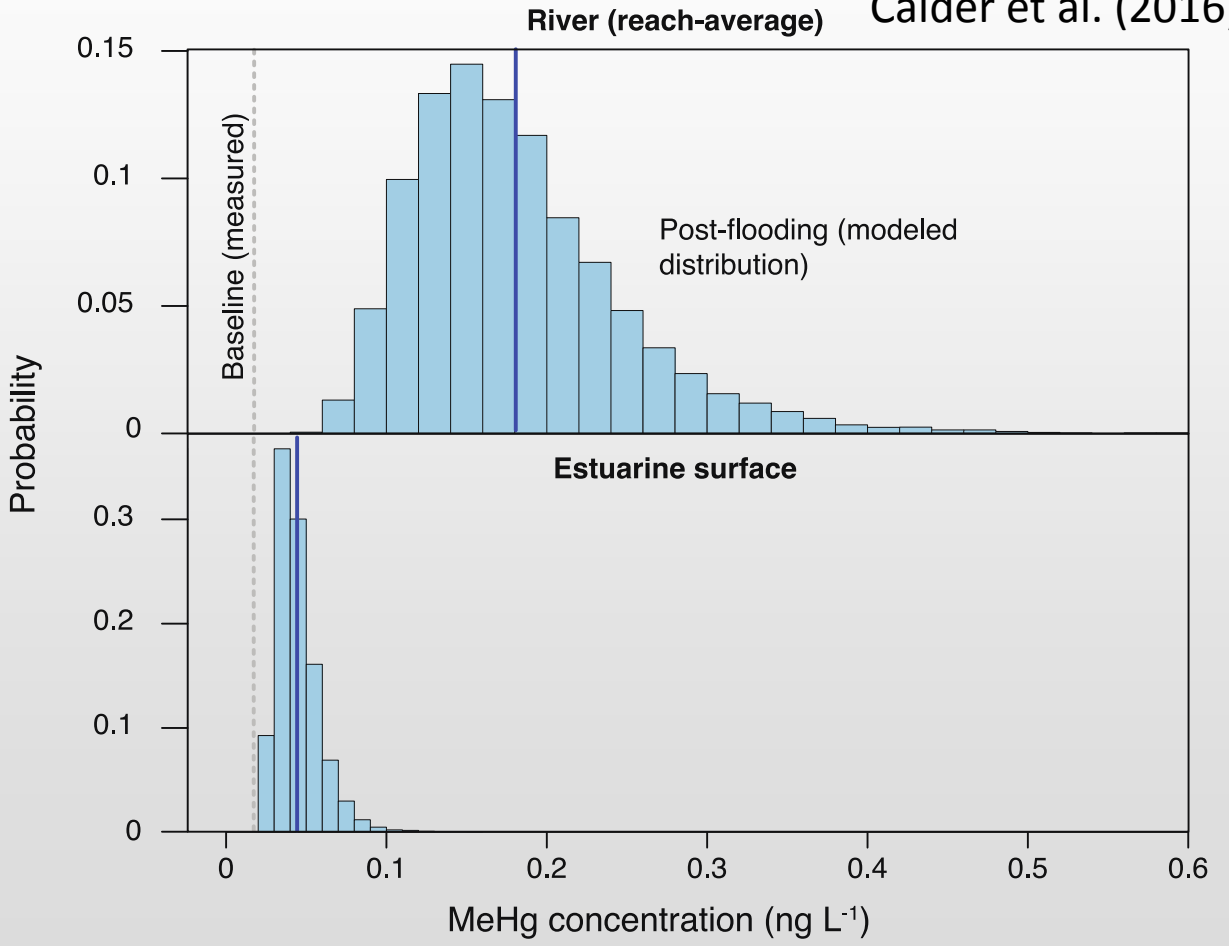
- Partition coefficient (measured)
- Shear stresses (Nalcor reservoir modeling used)



Downstream transport and bioaccumulation

- ΔMeHg in water column plugged into baseline budget
  - Peak increase in river and Lake Melville upper range
- Uncertain parameters
  - Degradation of terrestrially complexed MeHg (range from Schartup et al. 2015)
  - Lifetime habitat fractions of certain species

Calder et al. (2016)



Isotope data used to determine habitat fractions

- MeHg increases a function of time spent foraging in each environmental compartment
  - River → highest increases
  - Sea → no increase
  - Lake Melville → in between
- Lifetime fraction ≠ foraging fraction
- Foraging fractions constrained with isotopic signatures

ENVIRONMENTAL Science & Technology

Article

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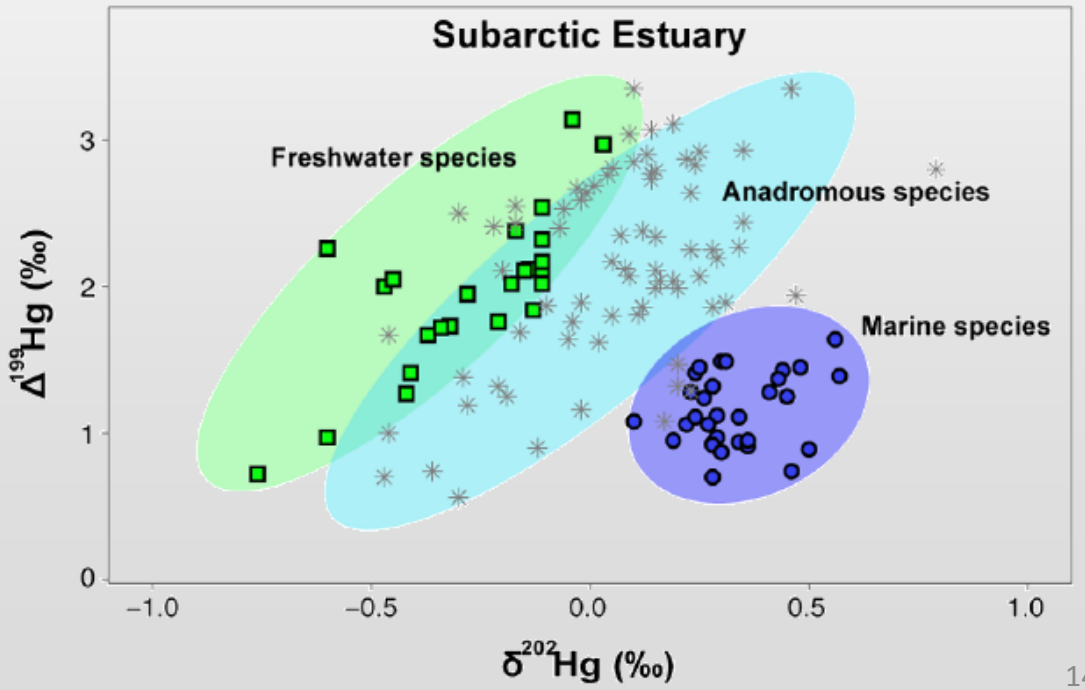
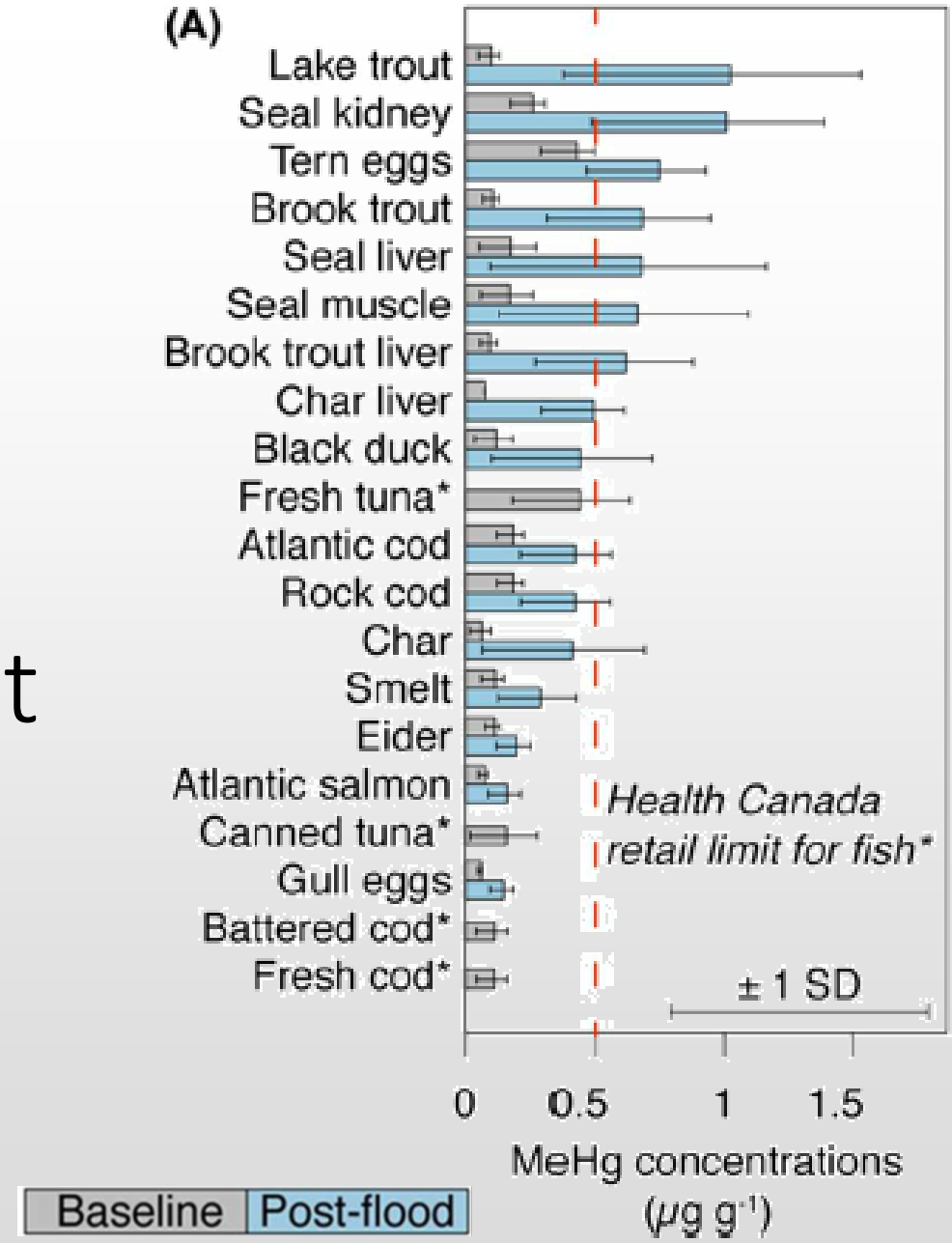
Environmental Origins of Methylmercury Accumulated in Subarctic Estuarine Fish Indicated by Mercury Stable Isotopes

Miling Li,[*,†,‡] Amina T. Schartup,[†,‡] Amelia P. Valberg,[†,‡] Jessica D. Ewald,[‡] David P. Krabbenhoft,[§] Runsheng Yin,[∥,⊥] Prentiss H. Balcom,[‡] and Elsie M. Sunderland[†,‡]



Isotope and literature data used to assign habitat weights to species to project peak MeHg levels



Calder et al. (2016)

Comparison of forecasts

- Harris et al. 2008 (statistical)
  - 1.8 – 4.7x increase
- Harris et al. 2010 (mechanistic)
  - 2.3 – 6.0x increase
- Calder et al. 2016 (mechanistic)
  - 8.8x (river) + 2.6x (estuary) + 1.0x (sea) → mean forecasts
  - Brook trout → 6.8x increase
  - Ouananiche → 8.8x increase
  - Atlantic salmon → 2.3x increase

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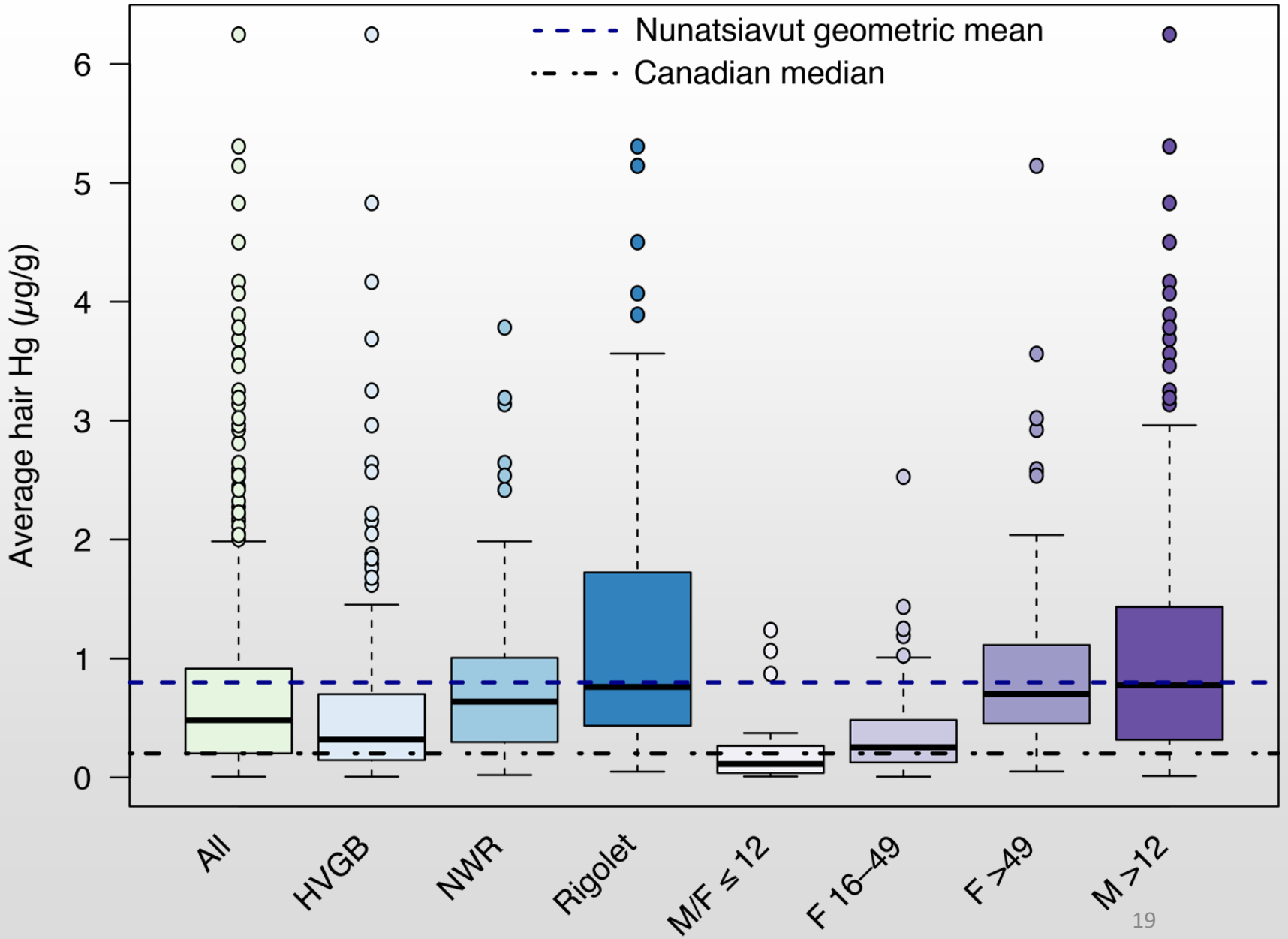
Lake Melville Inuit Health Study

- Dietary survey + Hg exposure assessment
  - Three seasons (2014)
  - 64 local foods + 24 store-bought seafoods
- 1,145 Inuit recruited from HVGB, NWR, Rigolet
  - Hair samples for 576
- Baseline MeHg exposure assessment
  - Magnitude
  - Sources

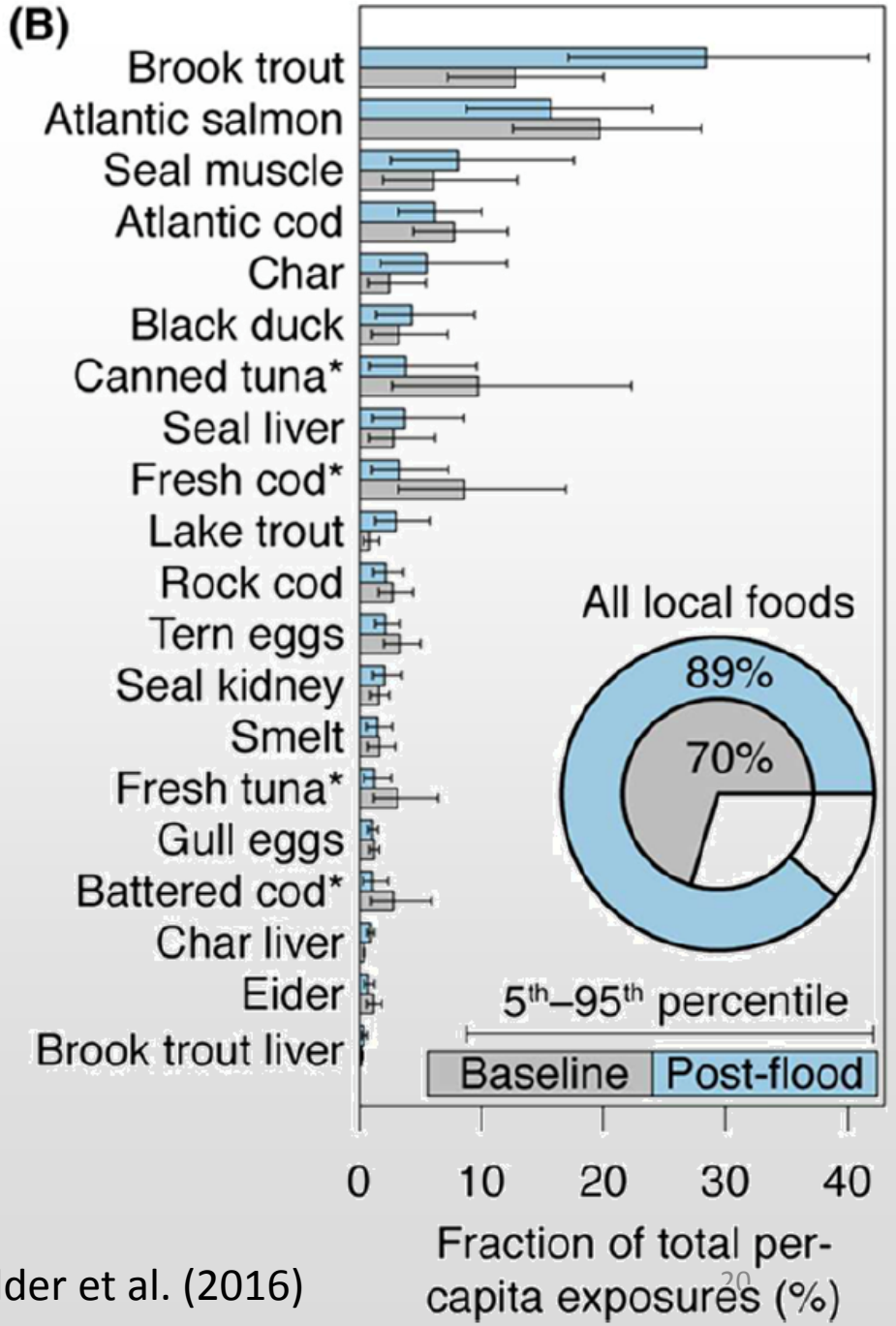
Calder et al. (2016)

MeHg exposures are higher than Canadian average and have long tail



Local foods are primary per-capita sources MeHg exposure

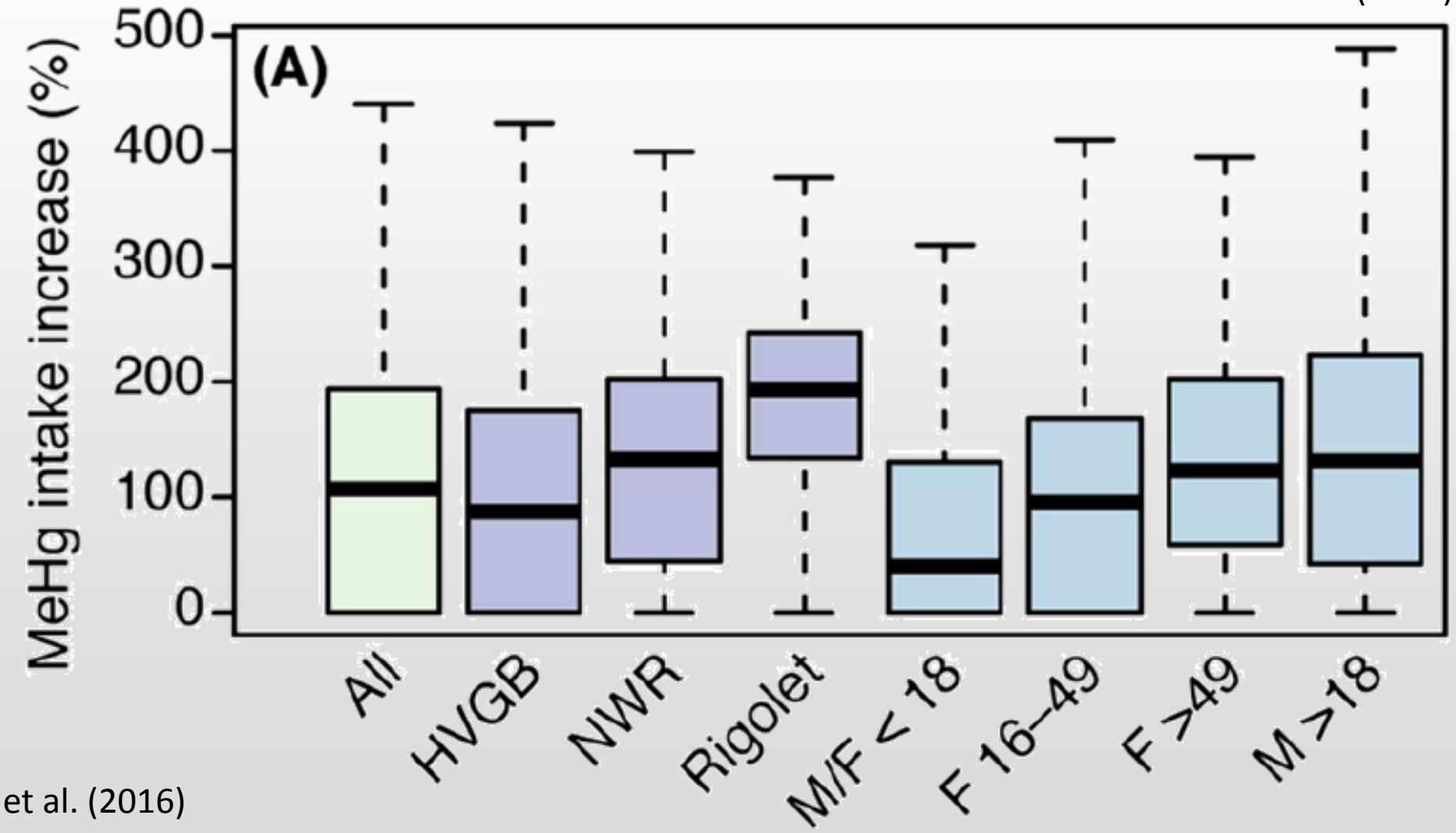
- Local foods → 70% of MeHg exposures at baseline, ~90% post-flooding (no change in diet)



Calder et al. (2016)

MeHg exposure increases vary widely

Calder et al. (2016)



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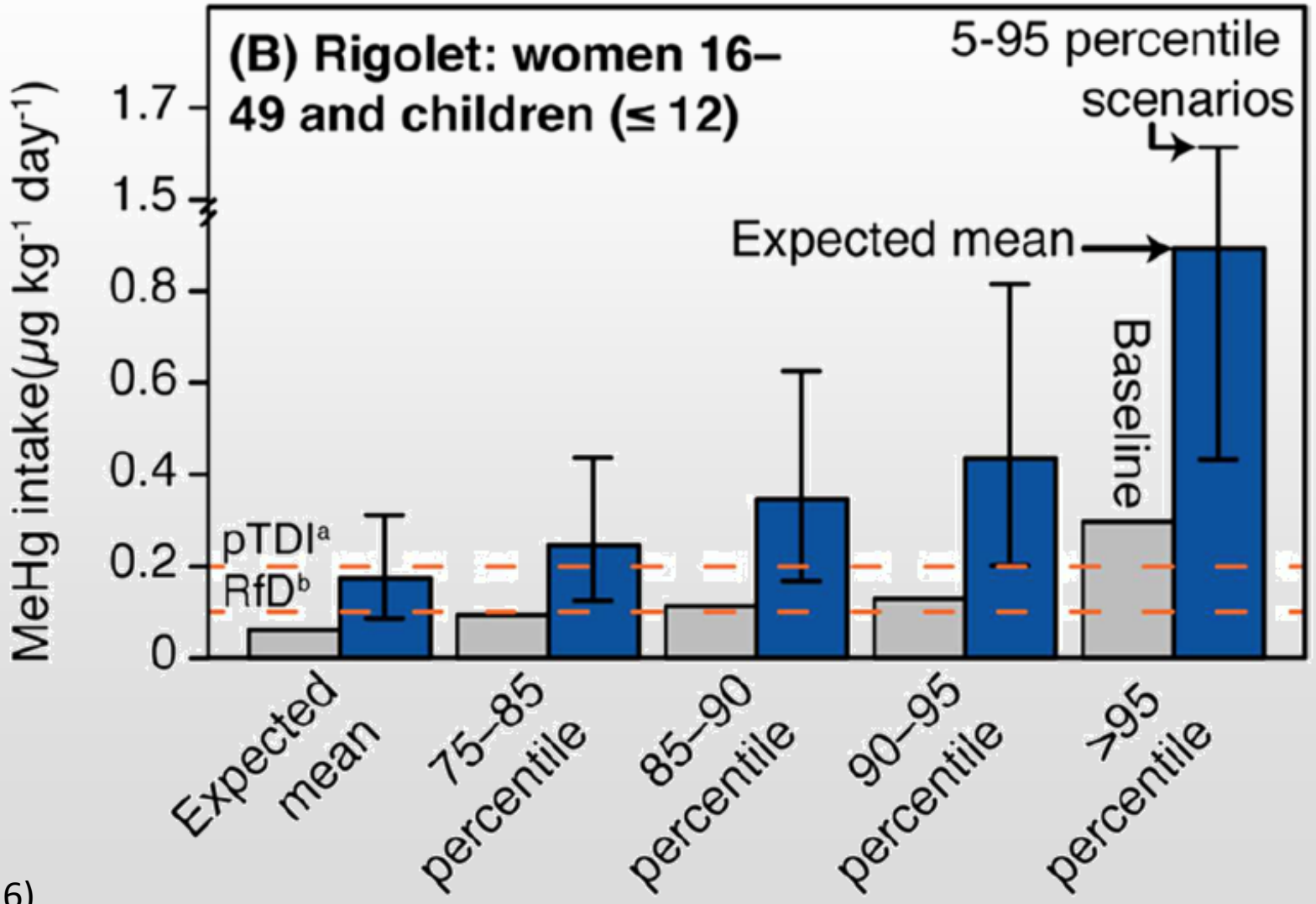
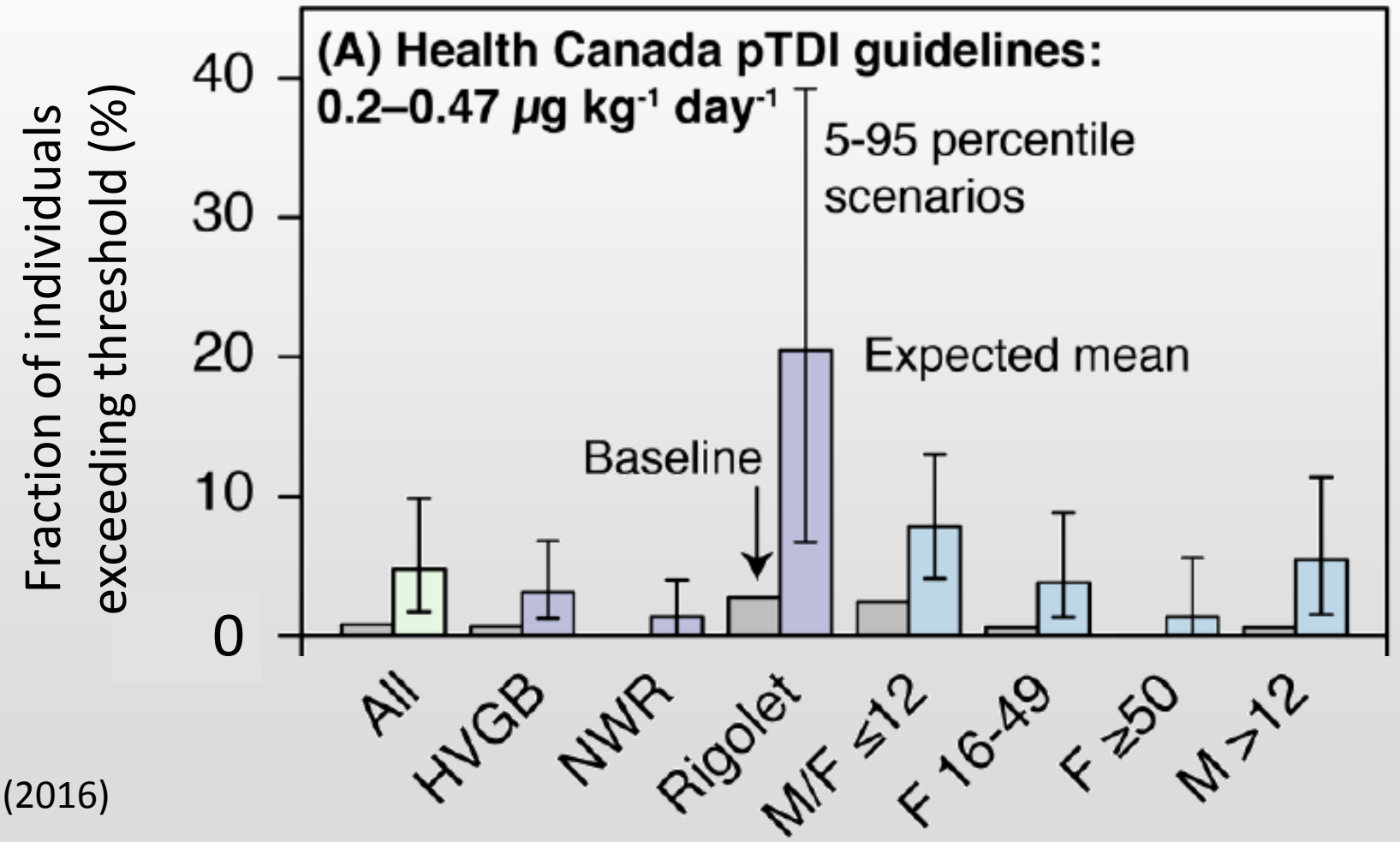


Calder et al. (2016)

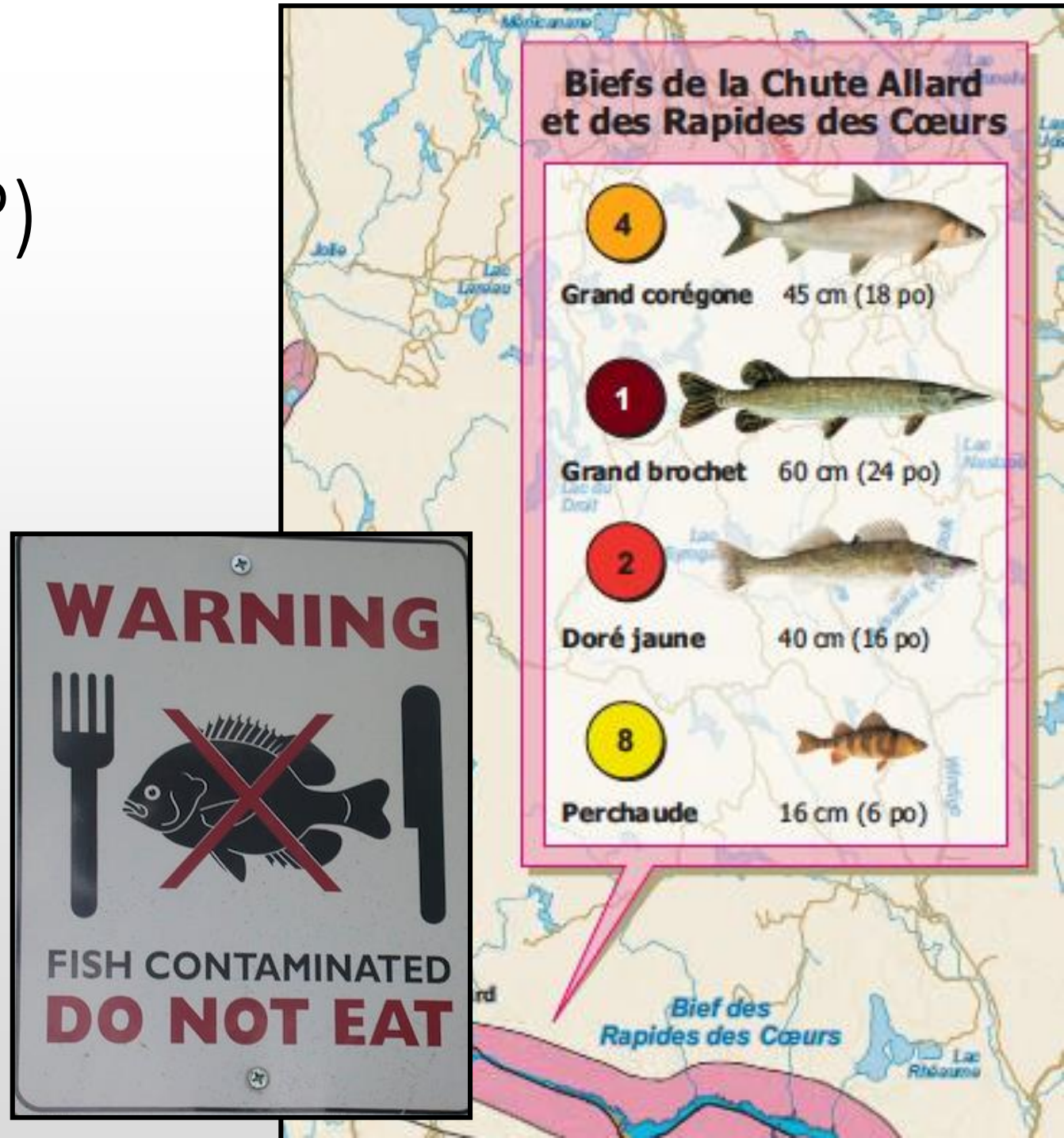
Prevalence of exceedances of pTDI/RfD increases greatly



Calder et al. (2016)

Agenda for Webinar 3 (comments/requests?)

- Underlying assumption for exposure forecasts: no changes in diet
- Diets often change
  - Food advisories
  - Fears about food quality
- Food advisories are default policy response
- Is it health protective?



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Other questions? Thank you!

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