Approaches to Ecosystem and Human Exposure to Mercury for Sensitive Populations

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Objectives

- Illustrate the approaches taken for ecosystem exposure as applied to mercury for the Clean Air Mercury Rule (CAMR)
- Convey the perspective of ecosystem exposure for sensitive populations
- Identify areas of overlap between human and ecosystem exposure

Disclaimer: Although this work has been reviewed and approved for presentation, it may not reflect Agency policy.

Introduction

Ecosystem exposure?

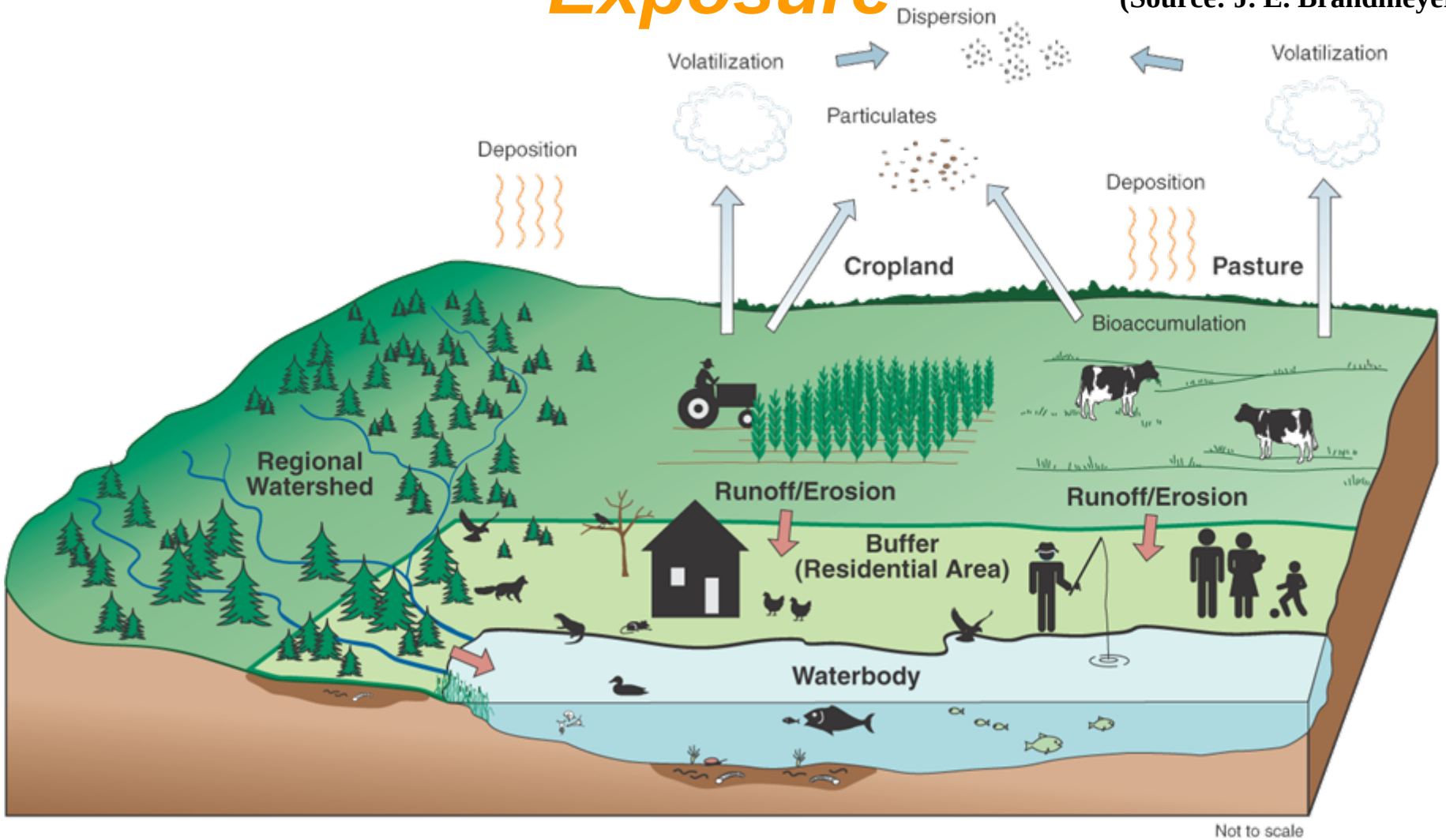
- **Environmental forecasting models (fate and transport of materials)**
  - **Mathematical simulation models of system dynamics**
  - **Environmental processes include, for example: transport, transformation, uptake and bioaccumulation**

Sensitive populations?

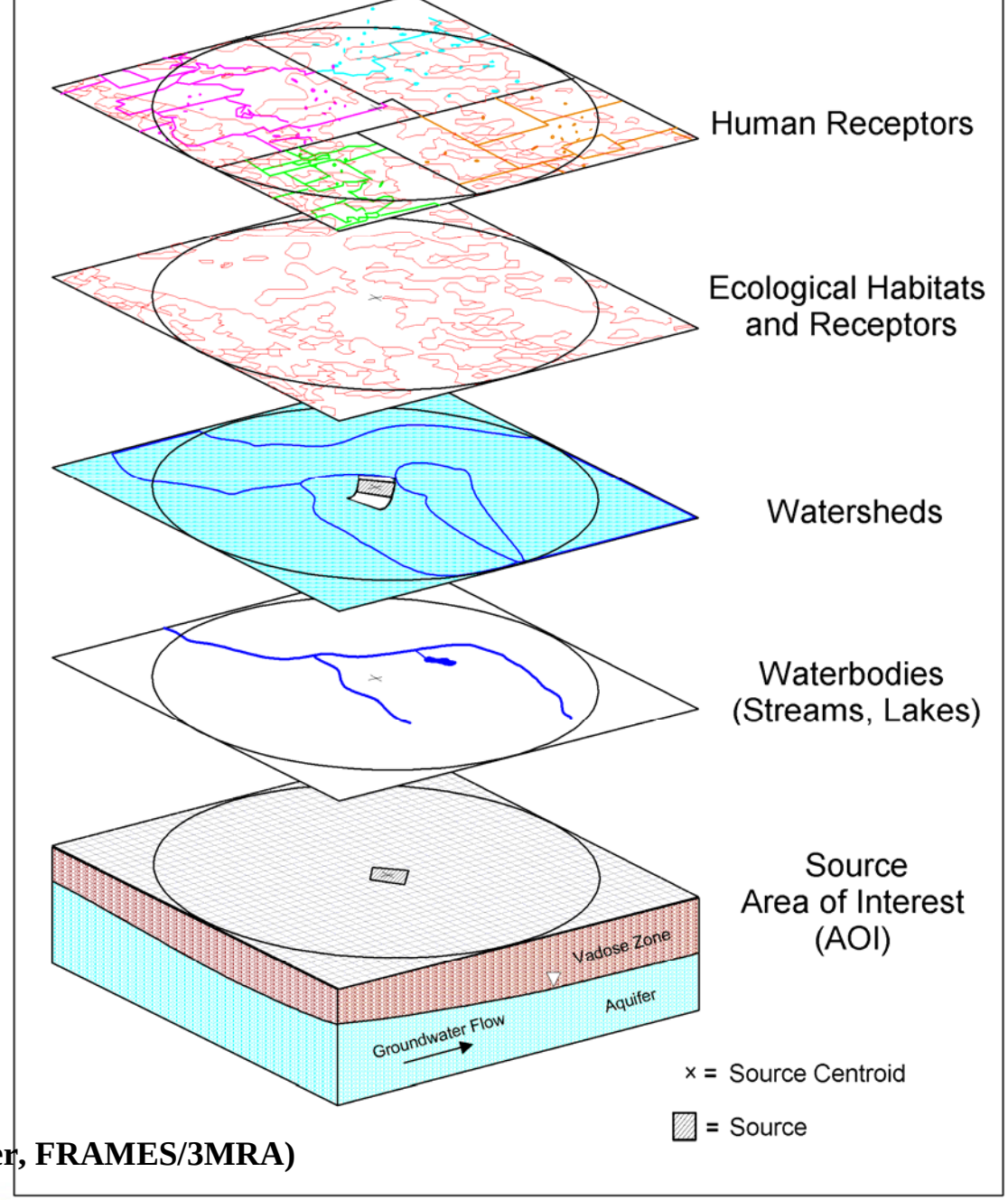
- **Watersheds, waterbodies, ecological populations and communites**

Conceptual Model of Ecosystem Exposure

(Source: J. E. Brandmeyer)

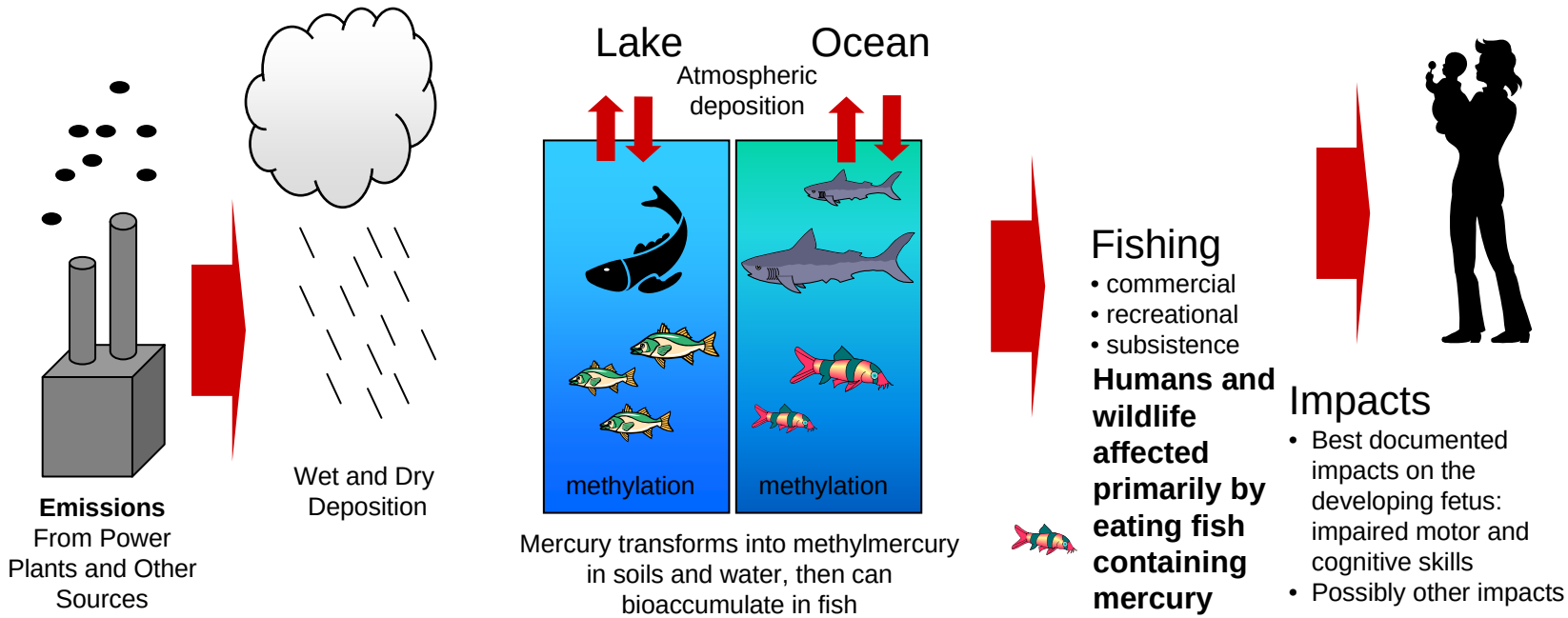


Source → Media → Biota → Receptors → Risk/Hazard

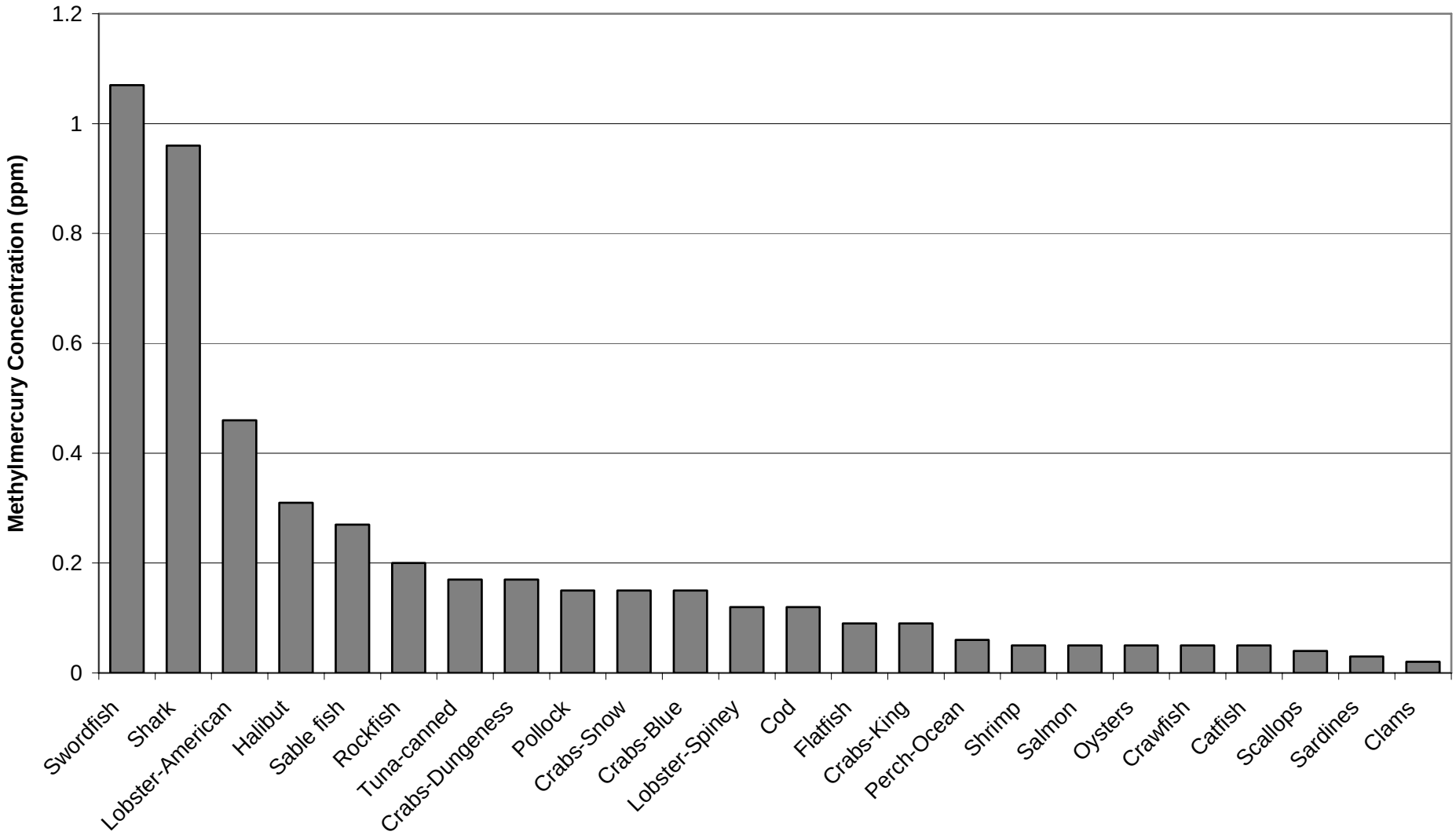


(Source: J. E. Brandmeyer, FRAMES/3MRA)

Conceptual Model of Human Exposure

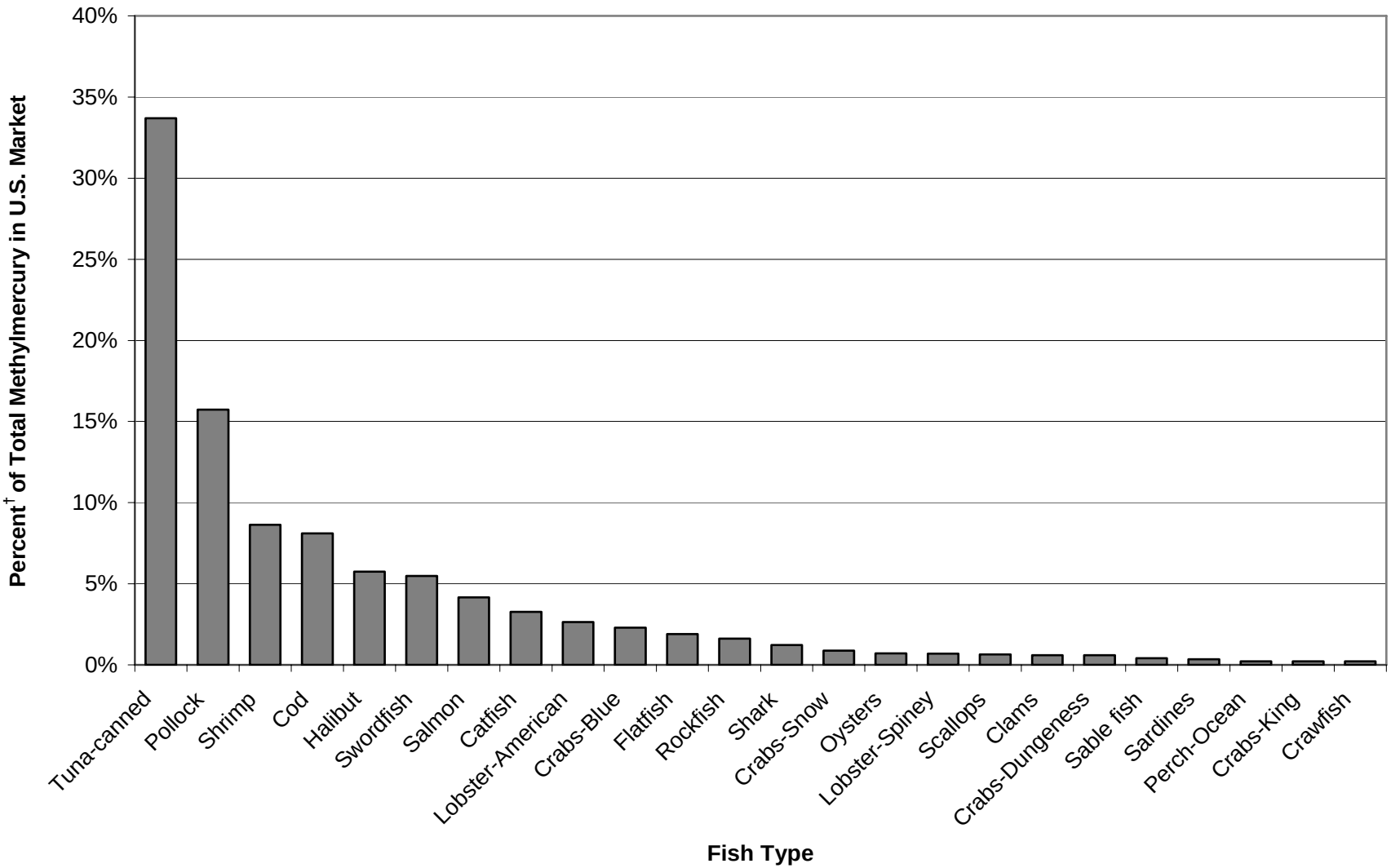


Mean Methylmercury Concentrations for "Top 24" Types of Fish Consumed in U.S. Commercial Seafood Market



(Source: Carrington and Bolger, 2002)

Percent (per capita) Methylmercury Intake by Fish Type for "Top 24" Types of Fish in U.S. Commercial Seafood Market



†Estimate based on the product of per capita fish consumption rates and mean methylmercury concentrations of each type of fish (Carrington and Bolger, 2003)

Uncertainties Related to Human Dietary Mercury Exposure/Dose Modeling

Environmental Modeling

Human Activity Modeling

PBTK and BBDR Modeling

Atmospheric emissions
Natural: Forest fires, volcanoes
Industrial: Power plants

Deposition to aquatic ecosystem

Ground water transport
Natural & industrial sources

Hg^0, Hg^{2+} → MeHg

Fish uptake of MeHg

Population Diet
Uncertainties:
- Amounts consumed
- Fish species consumed
- Fish preparation etc.

Regional Economy
Uncertainties:
- Local vs. imported fish
- Pricing and availability
- Processing, storage etc.

Season
Uncertainties:
- Fish species
- Fish maturation
- Fish size etc.

Dietary Ingestion

Absorption, Distribution Metabolism, Elimination and Toxicity (ADMET) Modeling
Uncertainties:
- Age, gender, lifestyle differences
- Physiological variability
- Physicochemical and biochemical variabilities
- Health status, activities
- Pregnancy/nursing
- Genetic susceptibilities

Target Tissue Dose
Brain
Kidney
Breast milk
Fetus / fetal brain

Toxicity/Adverse Effect
Neurological
Renal
Cardiovascular
[Genomic / Cytomic]

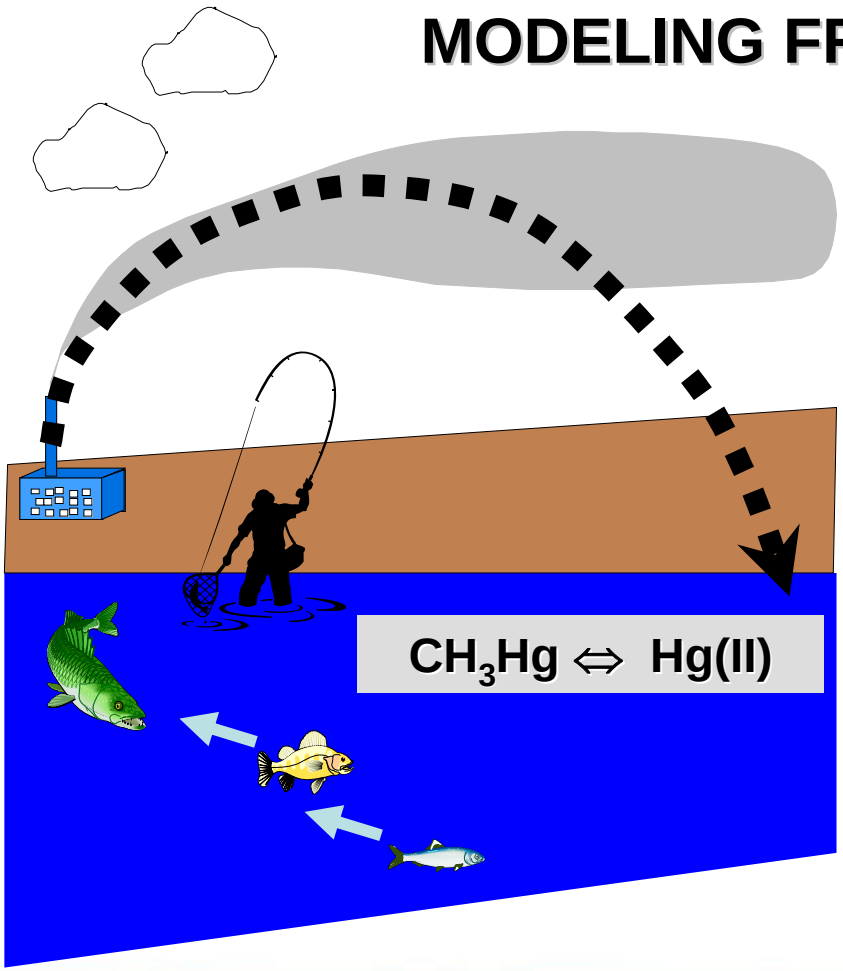
U.S. EPA Clean Air Mercury Rule CAMR (March 15th, 2005)

EPA needed to answer: what are the benefits to human and ecosystem health of reducing mercury emissions from coal-fired utilities?

What is the timing and magnitude of response of various ecosystems to reductions in atmospheric inputs?

Integrated Analysis is Required

MODELING FRAMEWORK



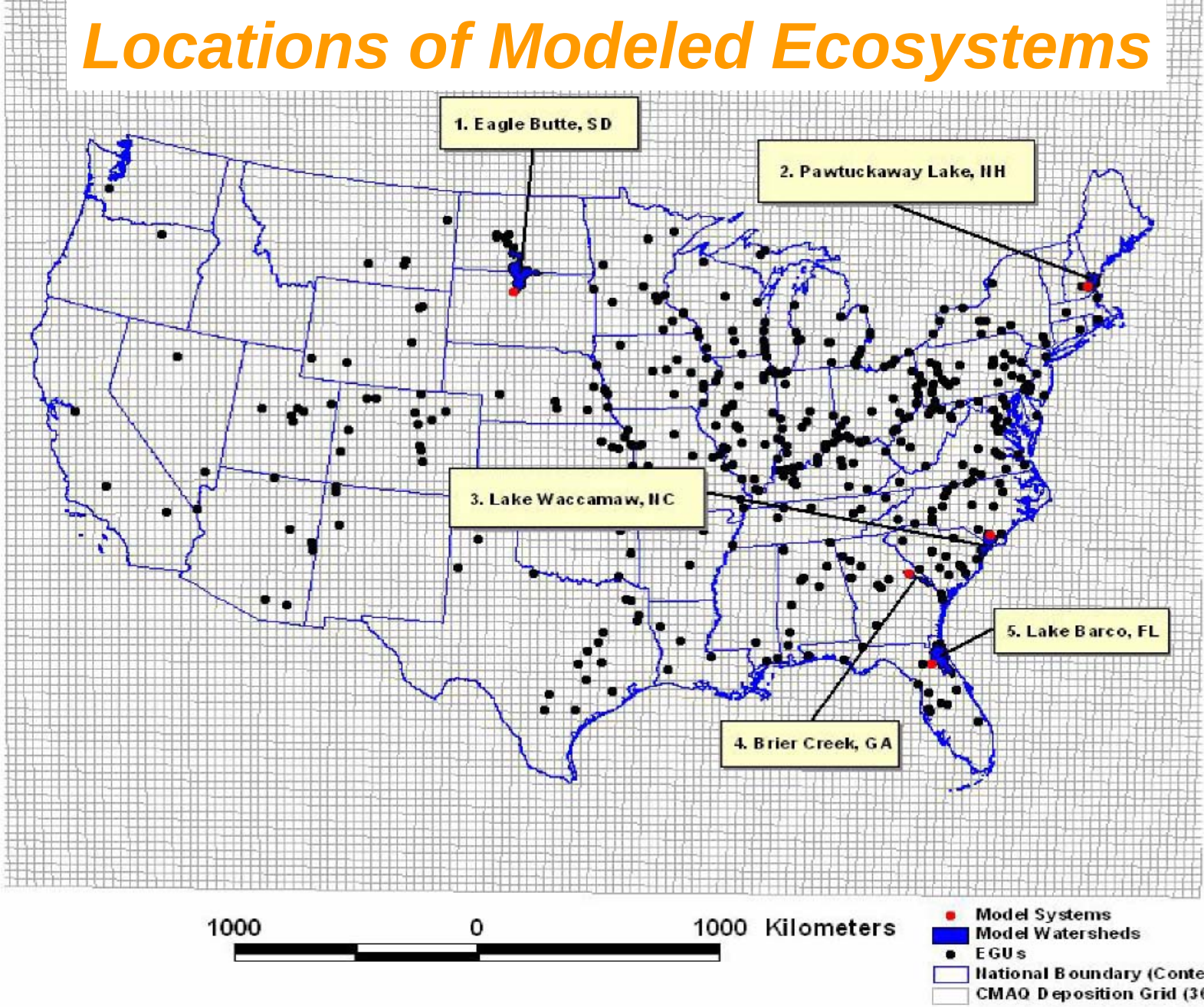
1. **Atmospheric:** ***HYSPLIT, CMAQ****
2. **Aquatic Fate and Transport:** ***MCM, WASP****
3. **Bioaccumulation:** ***BASS*, EcoFate***
4. **Human Exposure:** ***MENTOR Modeling System***

(* USEPA Models)

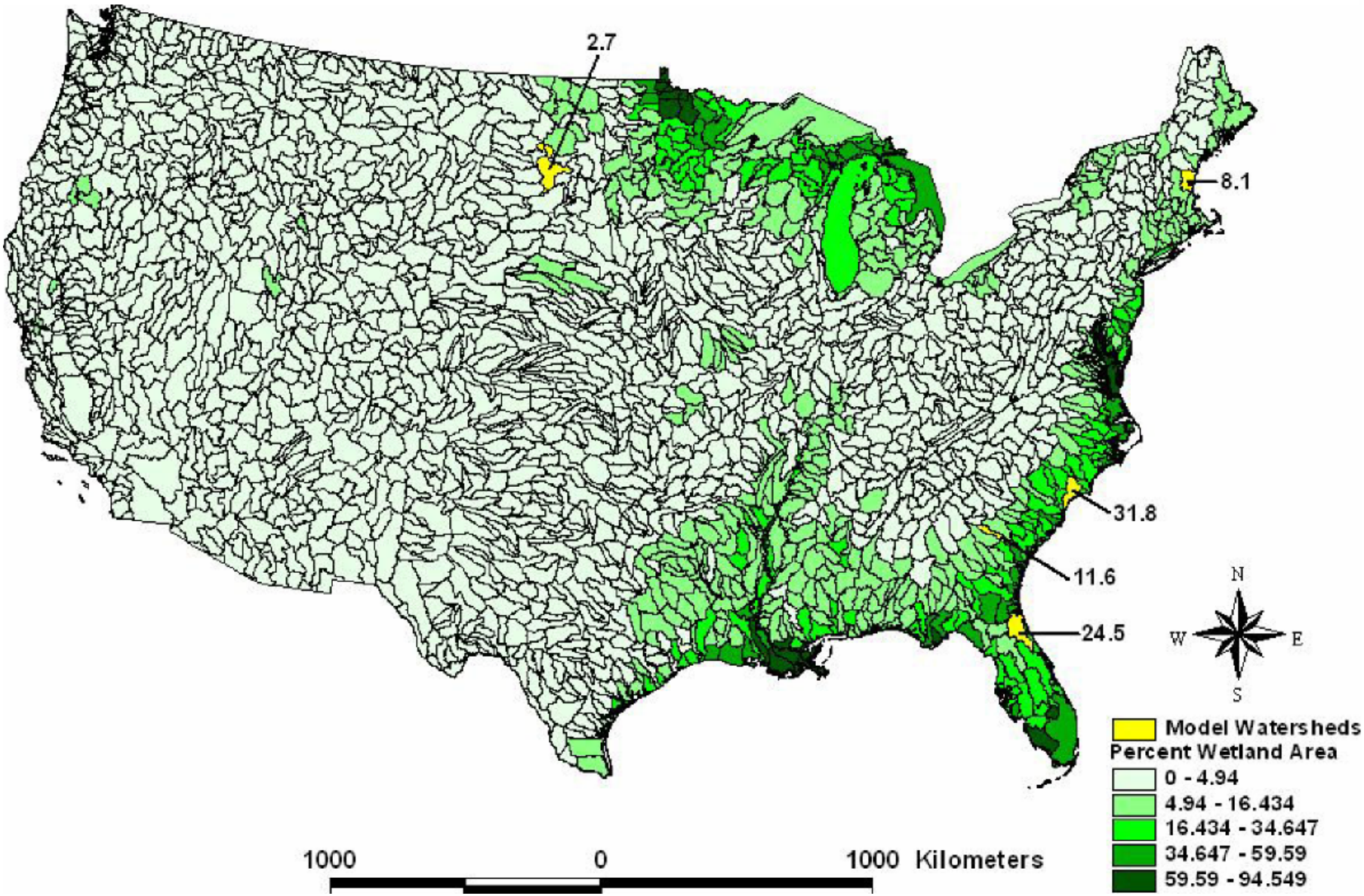
Model Ecosystems

- Lake Barco, FL
  - Small, southern seepage lake with negligible watershed
- Brier Creek, GA
  - Watershed dominated, coastal plain river
- Lake Waccamaw, NC
  - Large, shallow, well-mixed lake
- Lake Pawtuckaway, NH
  - Medium sized, stratified seepage lake
- Lee Dam, SD
  - Shallow, well-mixed farm pond

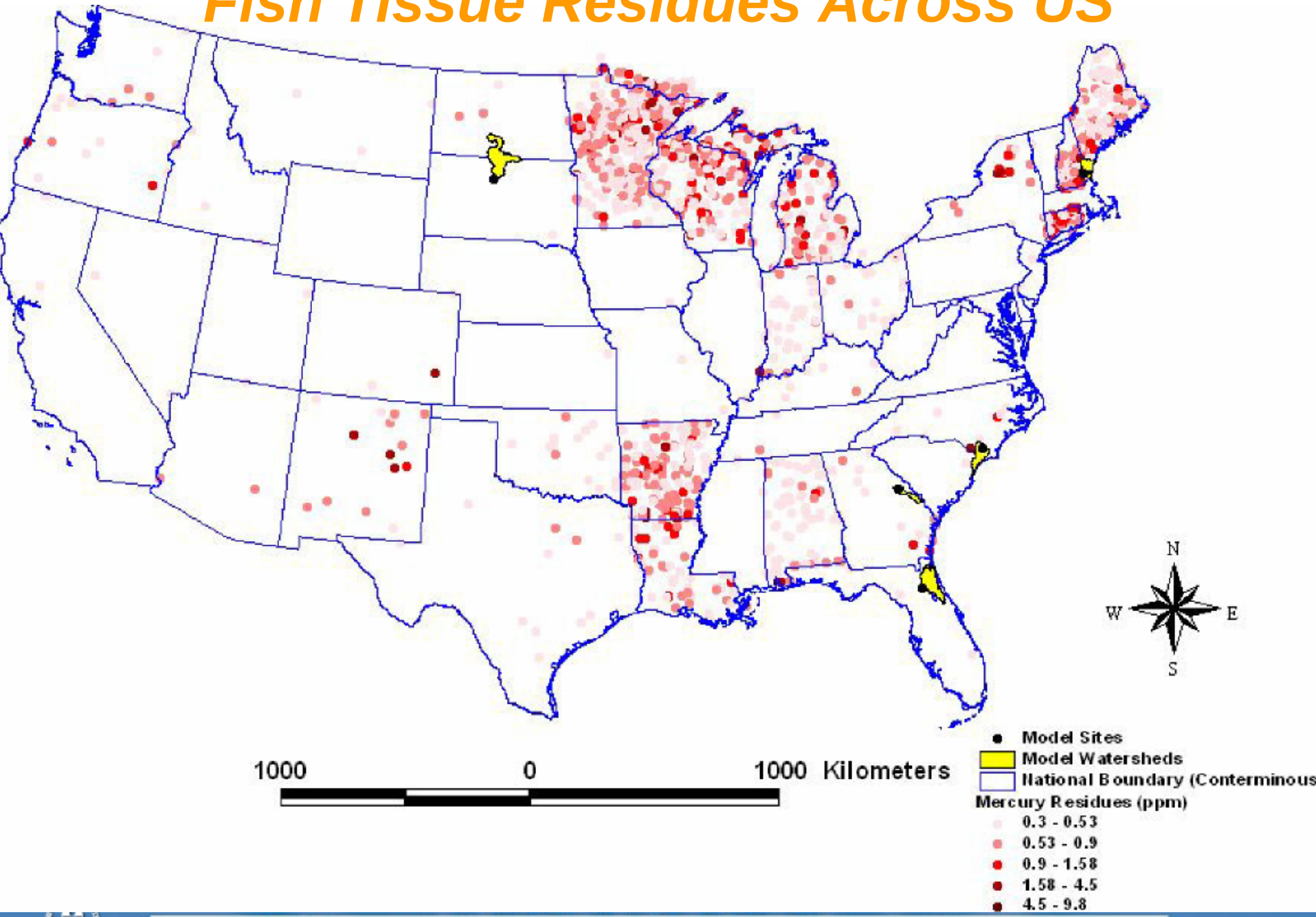
Locations of Modeled Ecosystems



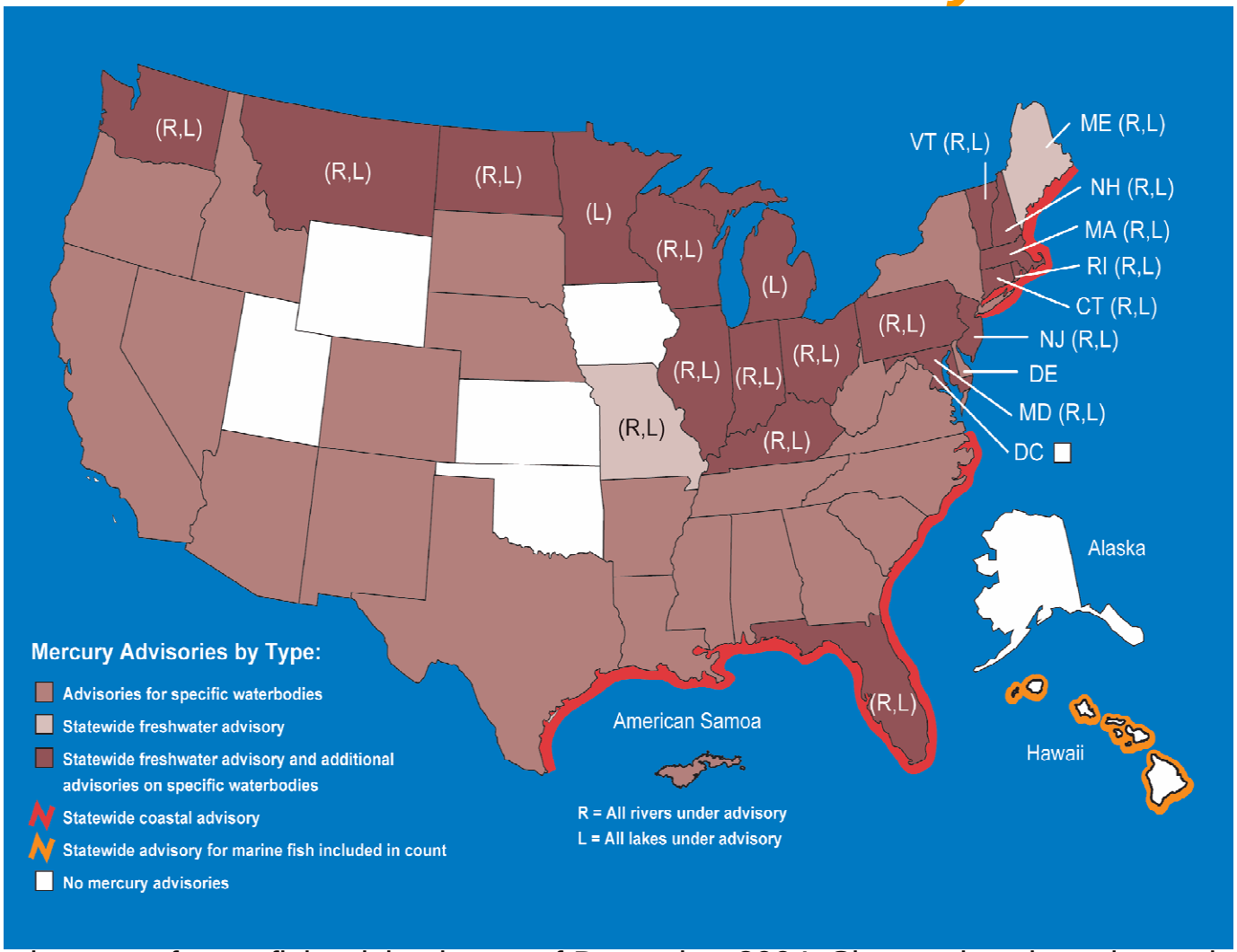
Watershed Percent Wetlands Land Cover Aggregated by 8-digit Hydrologic Unit Code



Fish Tissue Residues Across US



National Landscape of Fish Consumption Advisories for Mercury



Note: This was the map of state fish advisories as of December 2004. Since only selected waterbodies are monitored, the map does not reflect the full extent of contamination.

Ecosystem Sensitivity: Response times (yrs) for Fish Tissues to Reach Steady-state After 50% Mercury Reductions

Site	Fast	Medium	Slow
Eagle Butte	2	3	4
Lake Barco	14	28	43
Pawtuckaway Lake	34	56	64
Lake Waccamaw	1	1	2

Sensitive model parameter: depth of active sediment layer (1-3cm)

Landscape Ecophysiology and Dose Response

- **Watershed dominated systems are estimated to respond over 50 years (or more)**
- **Systems with low hydrologic residence times (high flushing rate) eliminate mercury at a greater rate**
- **Waterbody surface : depth ratio can alter ecosystem response significantly**
- **Fraction wetland area correlates well with methylmercury concentrations in receptors**

Bridging Human and Ecosystem Exposure

- **Continue to build consistent scientific and technical frameworks (both the formulation and expression of the science)**
- **Integrated approach also involves borrowing concepts across disciplines**
- **Identification of 'hotspots' – areas of greatest exposure and risk**

Acknowledgements

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