GLC Atmospheric Toxics Webinar Series – Mar 15, 2011

Neurochemical Biomarkers to Assess Effects of Toxic Substances on Wildlife in the Great Lakes

NIL BASU

Department of Environmental Health Sciences
School of Public Health, University of Michigan
Ann Arbor, MI

niladri@umich.edu
sitemaker.umich.edu/ecotoxicology.lab

Talk Overview – 2 Parts

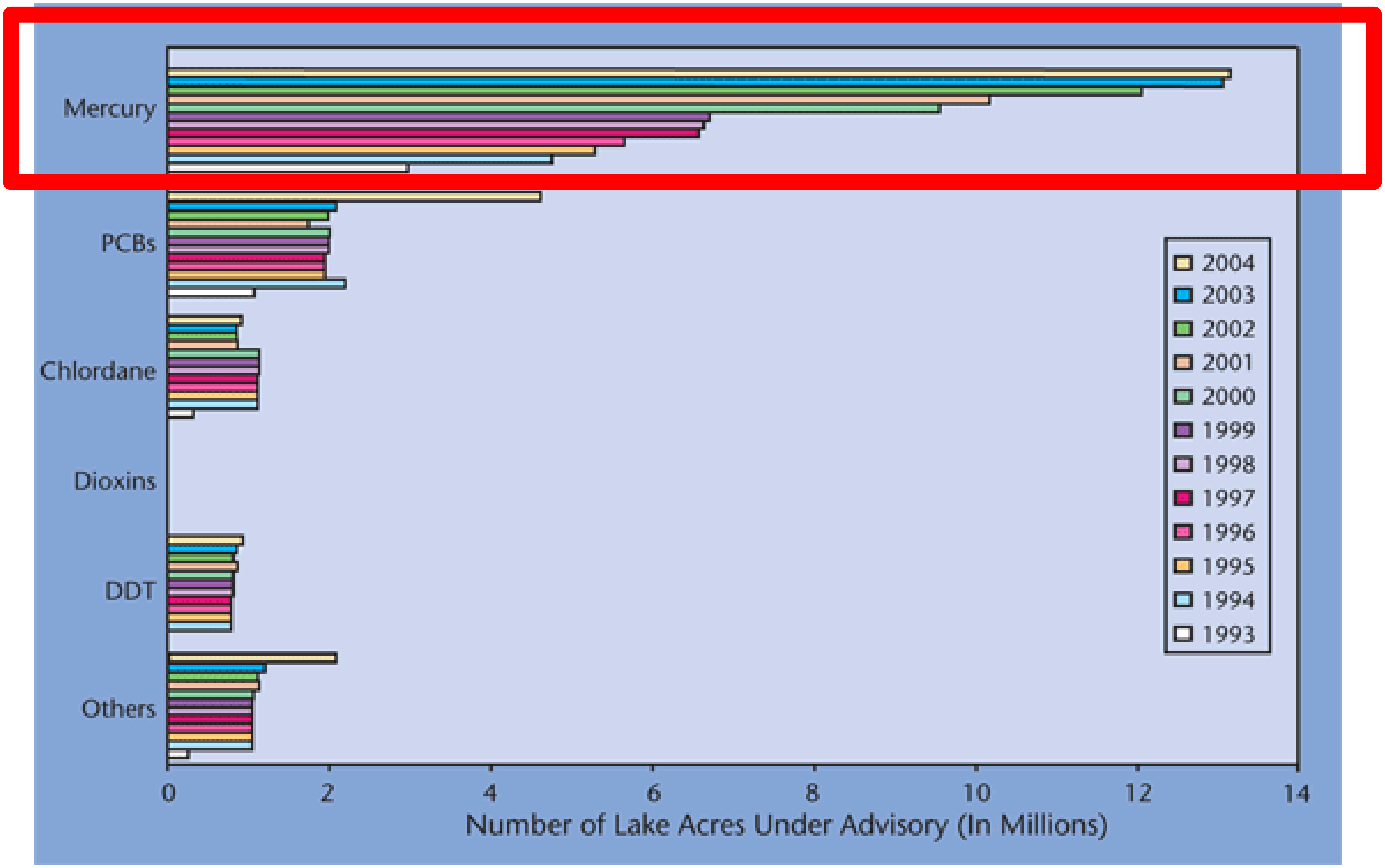
A) GLAD Multimedia Hg Study (Evers, Wiener)

- Co-leader, “Wildlife” group (w/Mike Meyer)
- Temporal and spatial gradients of mercury
- Biological effects in wildlife
- Participants noted at end

B) GLAD Neurochemical Biomarkers

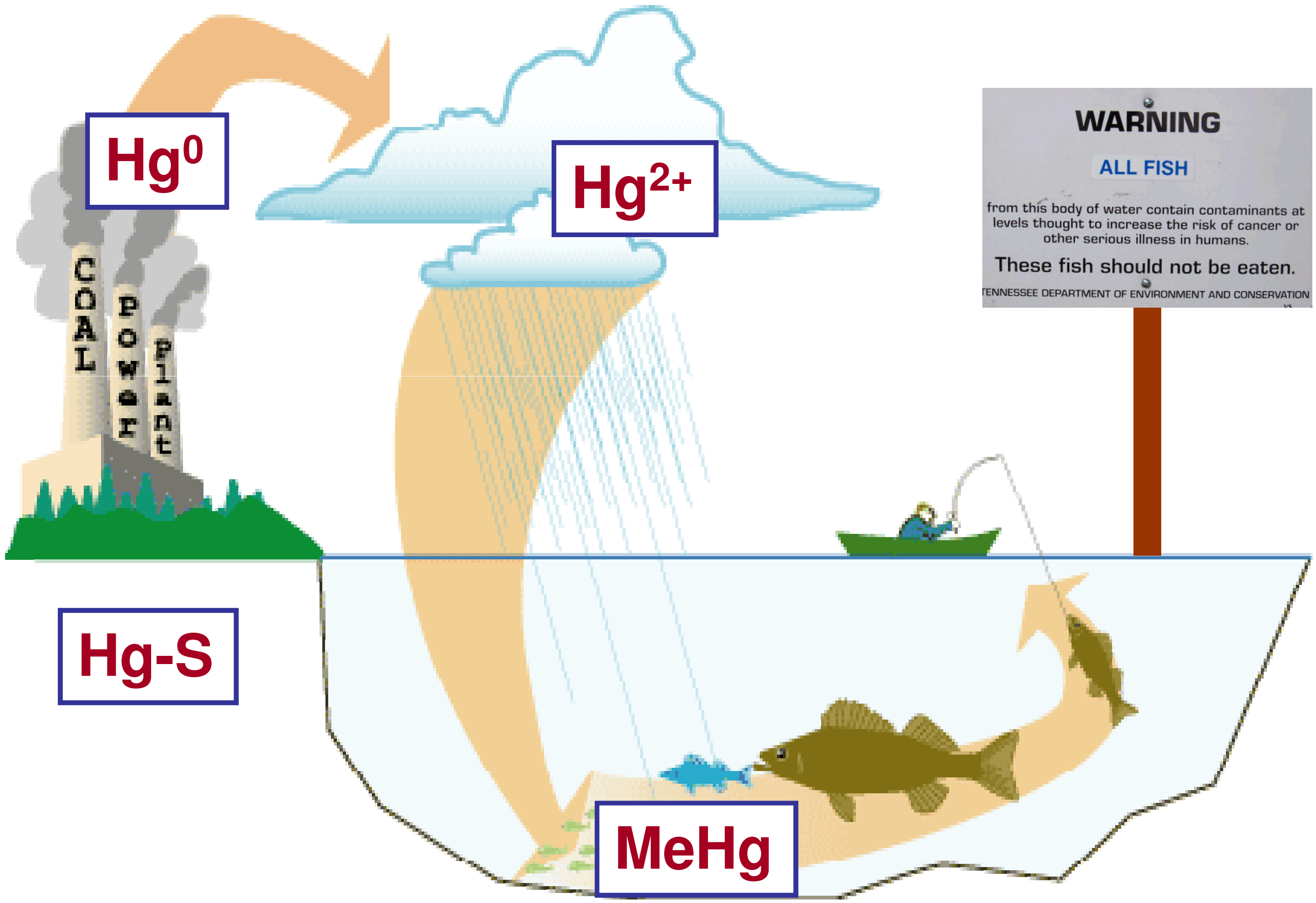
- Hg exposure/effect in eagles, otters, mink,etc
- Jen Rutkiewicz*, Peter Dornbos*, Sean Strom, Tom Cooley, + many more (*=students)

Goal: Top predator fish will be safe for consumption by all wildlife.
Status: Goal is not met in any Great Lake.
http://www.epa.gov/glnpo/glindicators/fishtoxics/topfisha.html [accessed Oct 1, 2009]

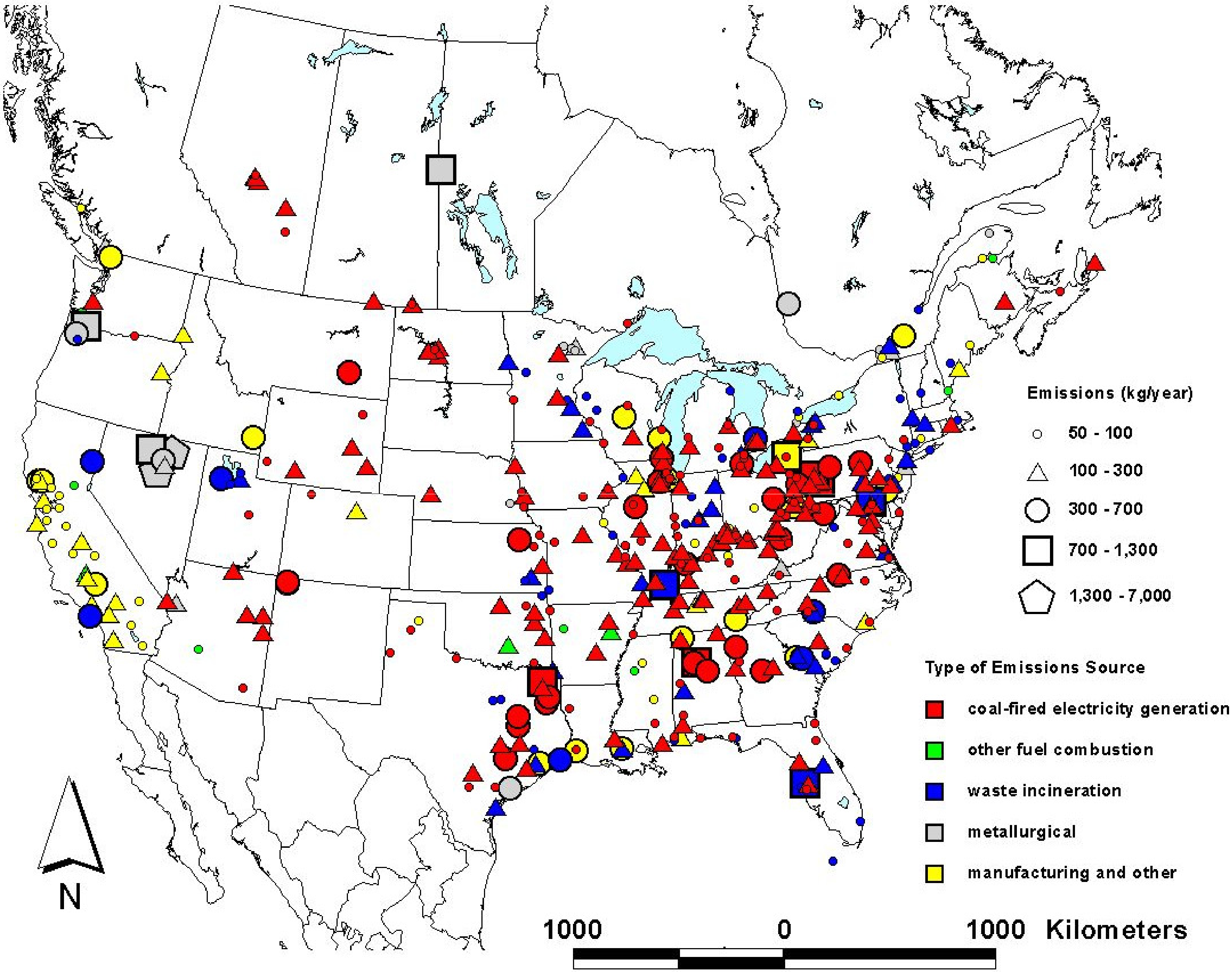


Number of Lake Acres Under Advisory for Various Pollutants in 2004
2004 National Listing of Fish Advisories (www.epa.gov/waterscience/fish)

A Simplified Mercury Cycle

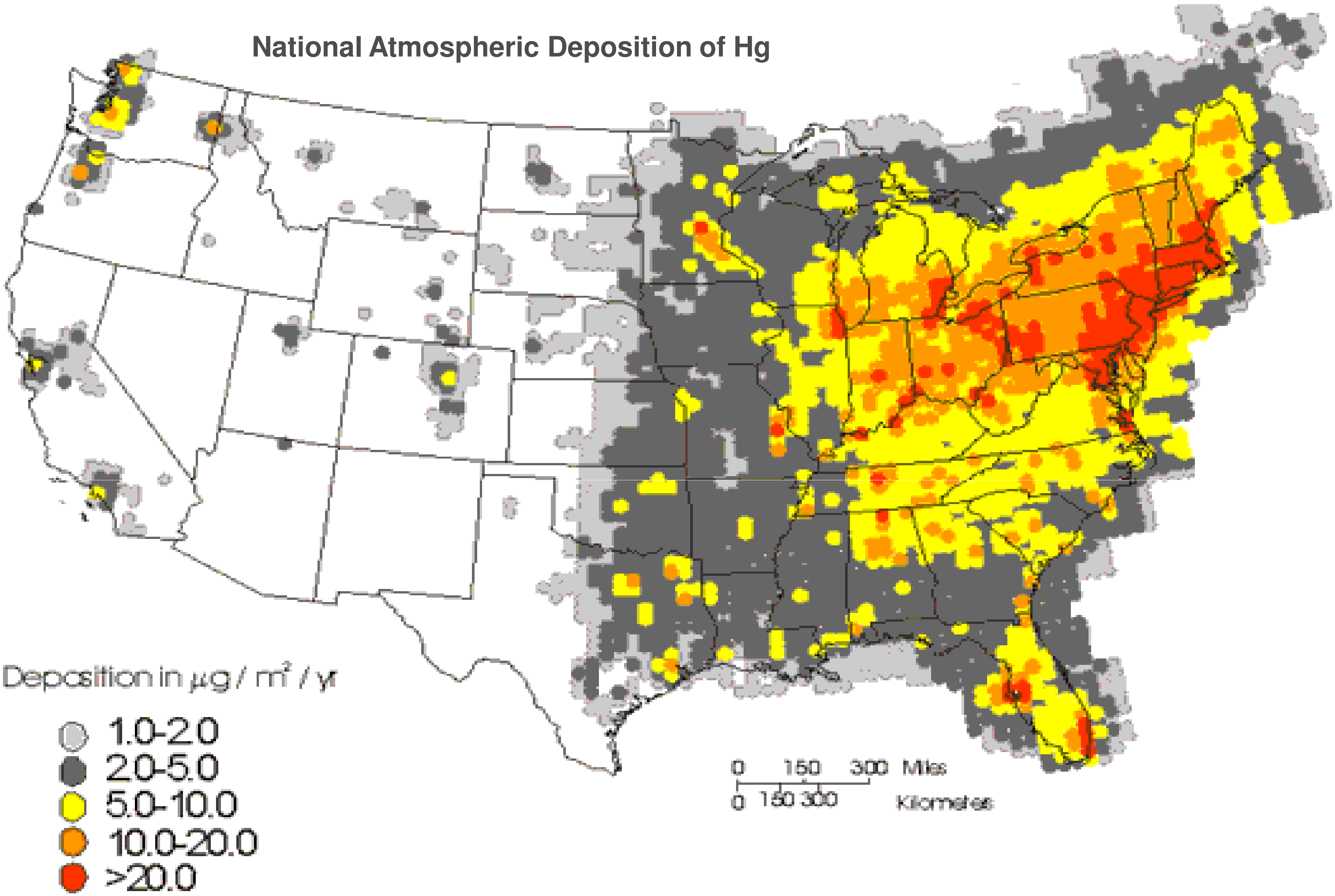


*** all steps are extremely complex!!!



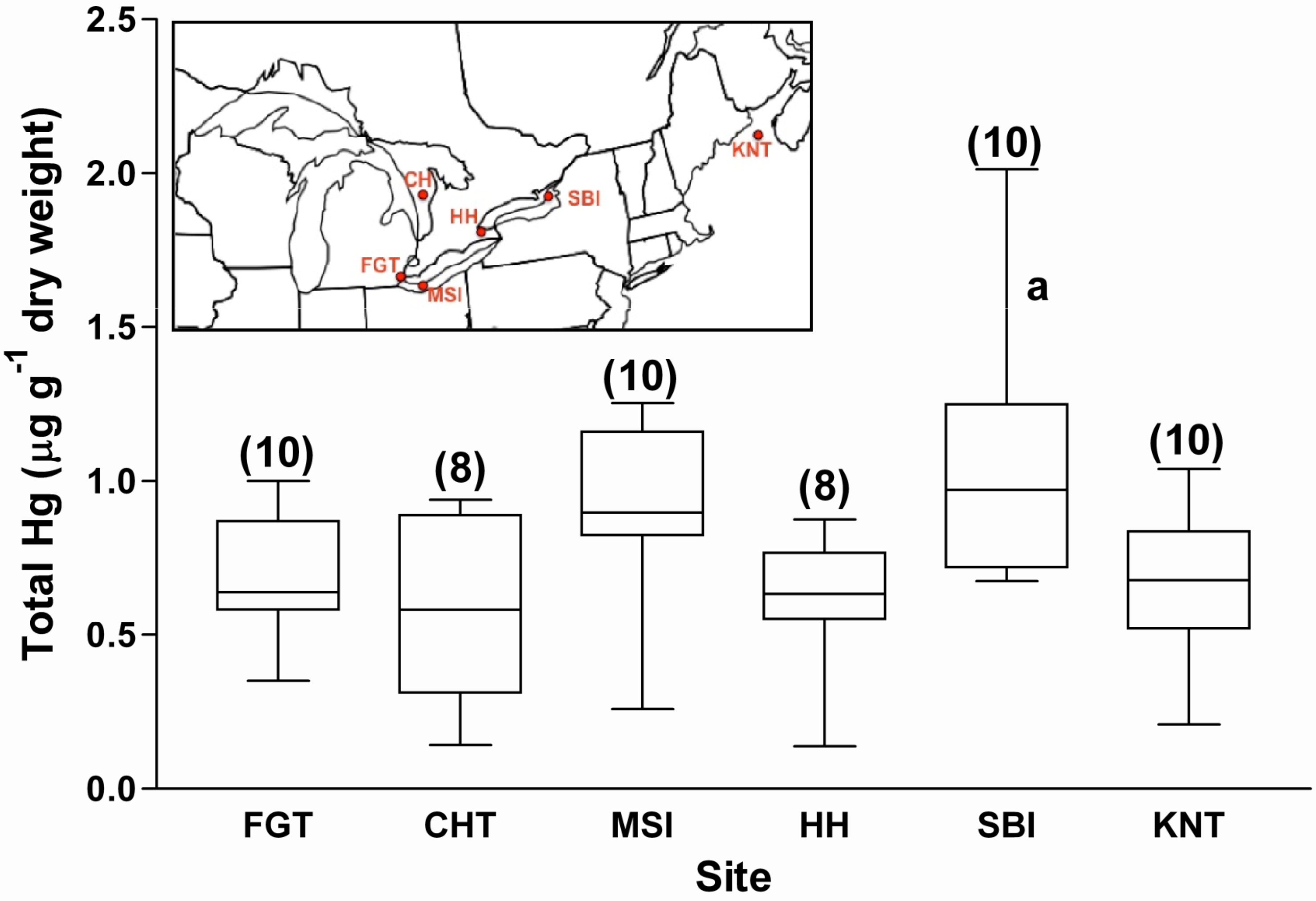
U.S. EPA 1999 National Emissions Inventory and 1995-1999 Environment Canada database

National Atmospheric Deposition of Hg



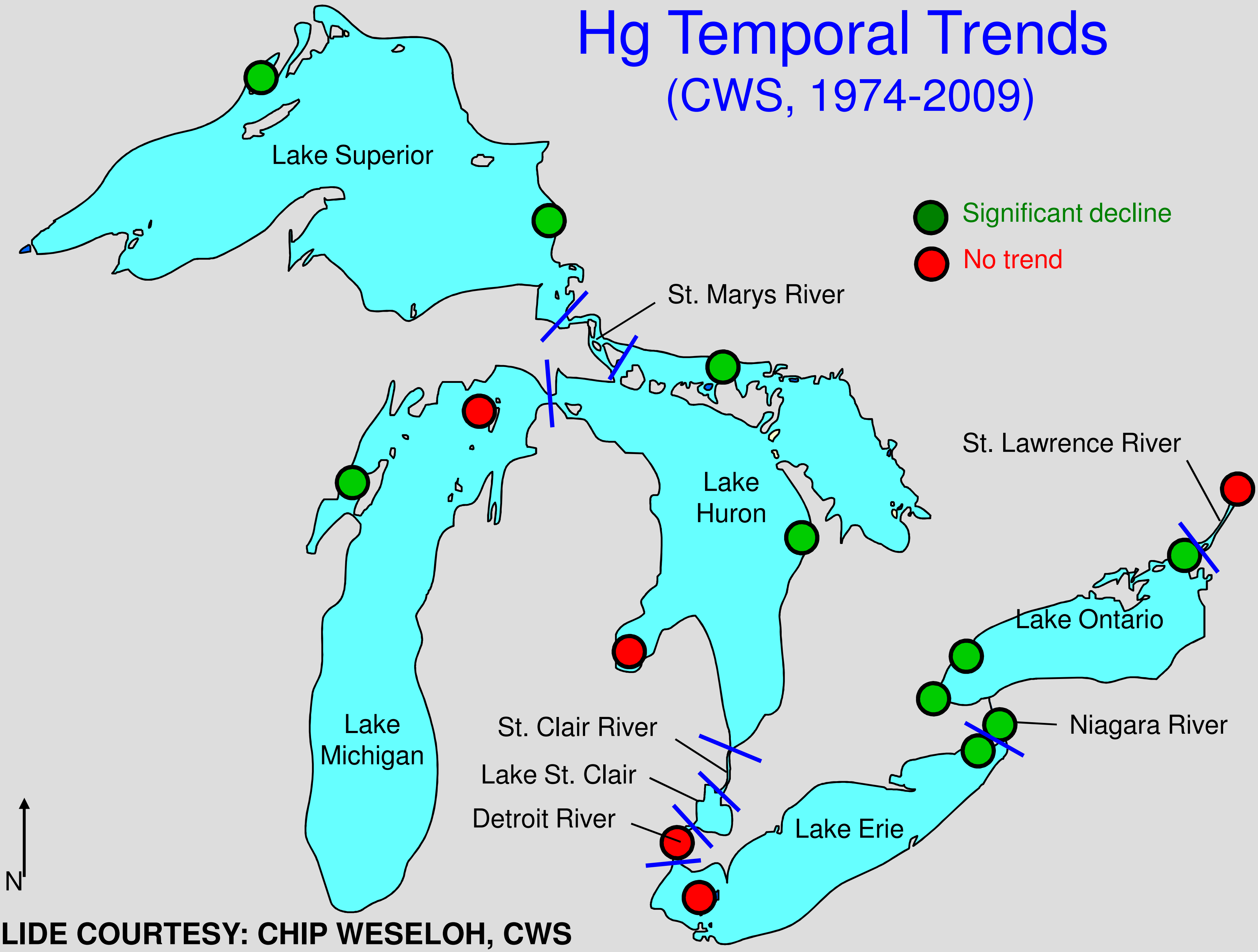
Source: US EPA, 1998, Mercury Report to Congress

Herring Gulls as sentinels



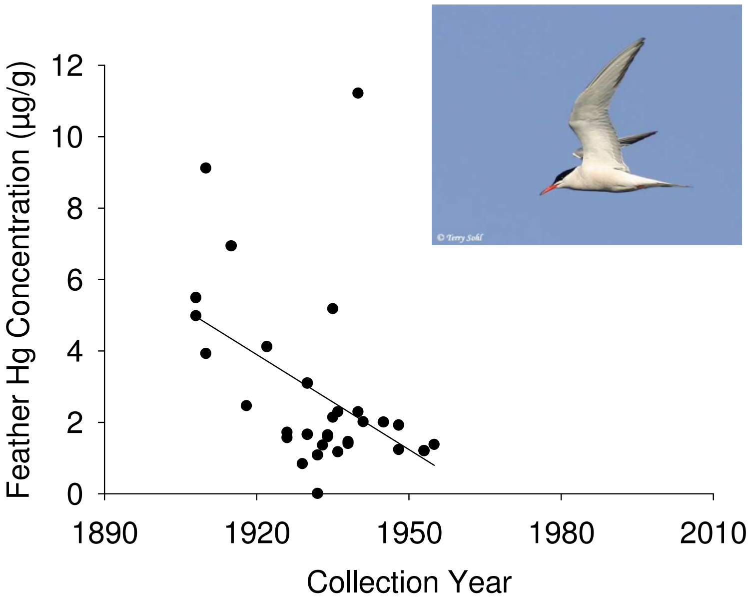
Rutkiewicz et al. 2010. Environ Poll 158: 2733-2737

Hg Temporal Trends
(CWS, 1974-2009)

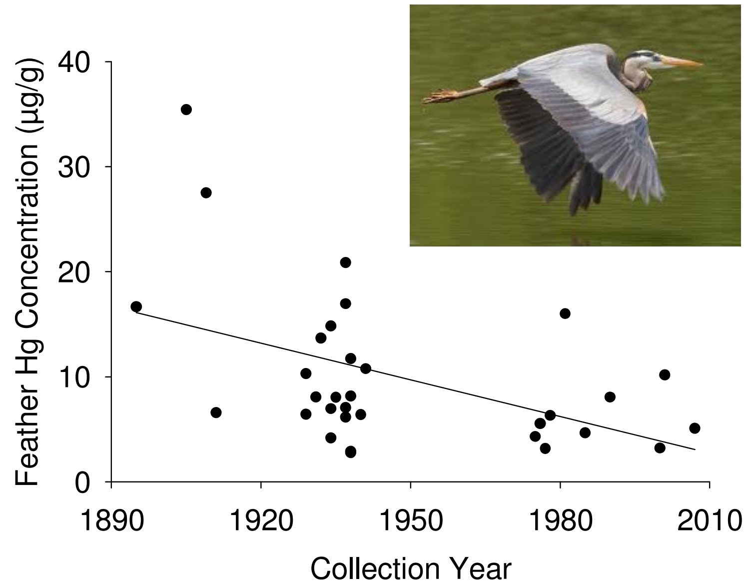


SLIDE COURTESY: CHIP WESELOH, CWS

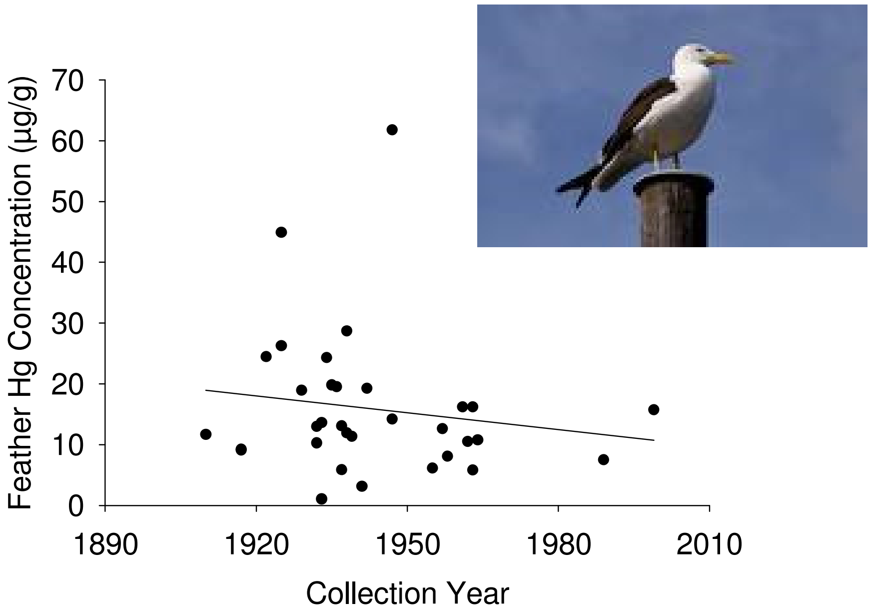
A. Common Tern



B. Great Blue Heron



C. Herring Gull



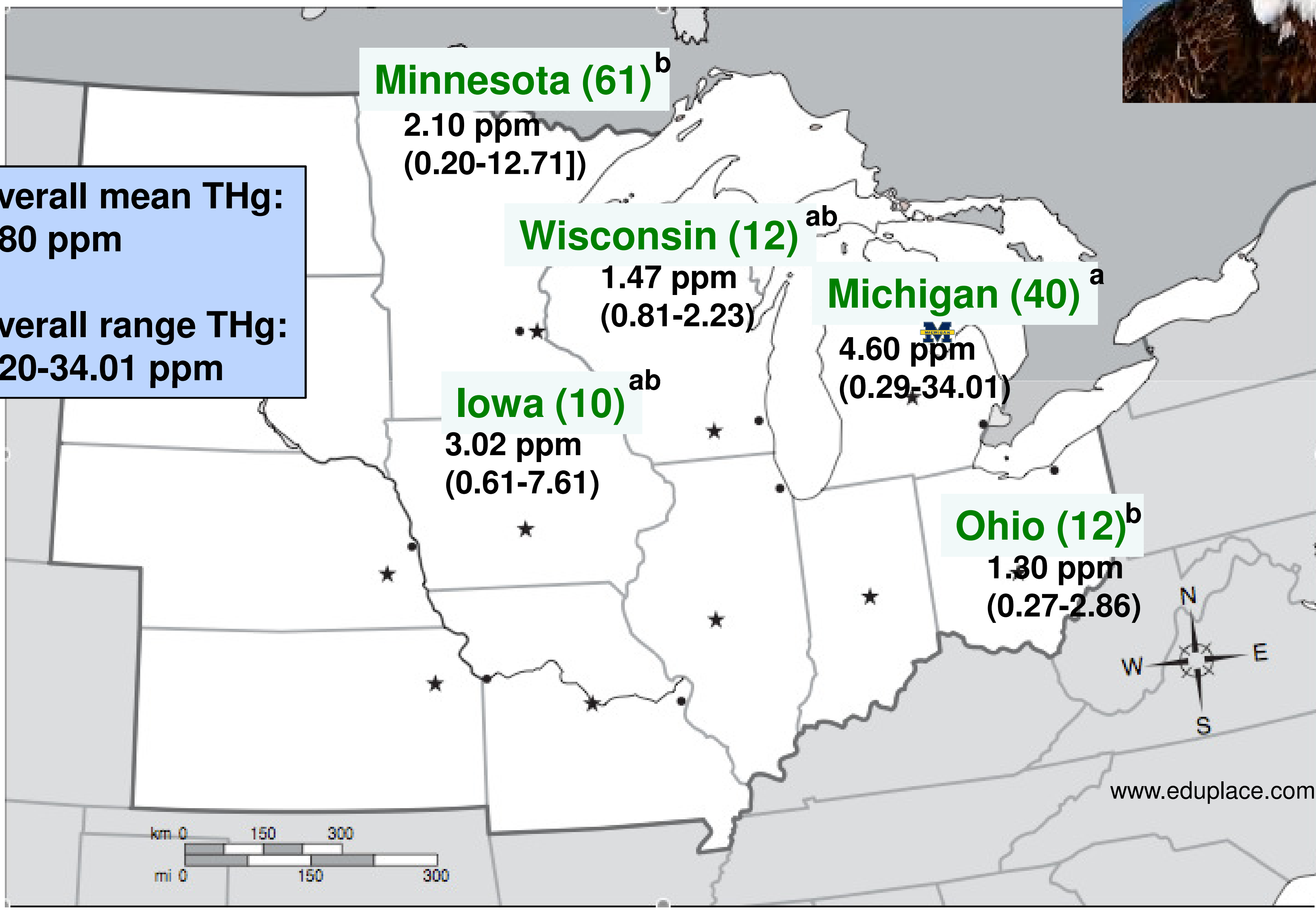
- **Museum specimens to analyze feather Hg 1895 -2007 from three Michigan birds**
- **0.09 – 0.16 ppm decrease/year**
- **Corroborate sediment data**

Head et al., under review. Ecotoxicology

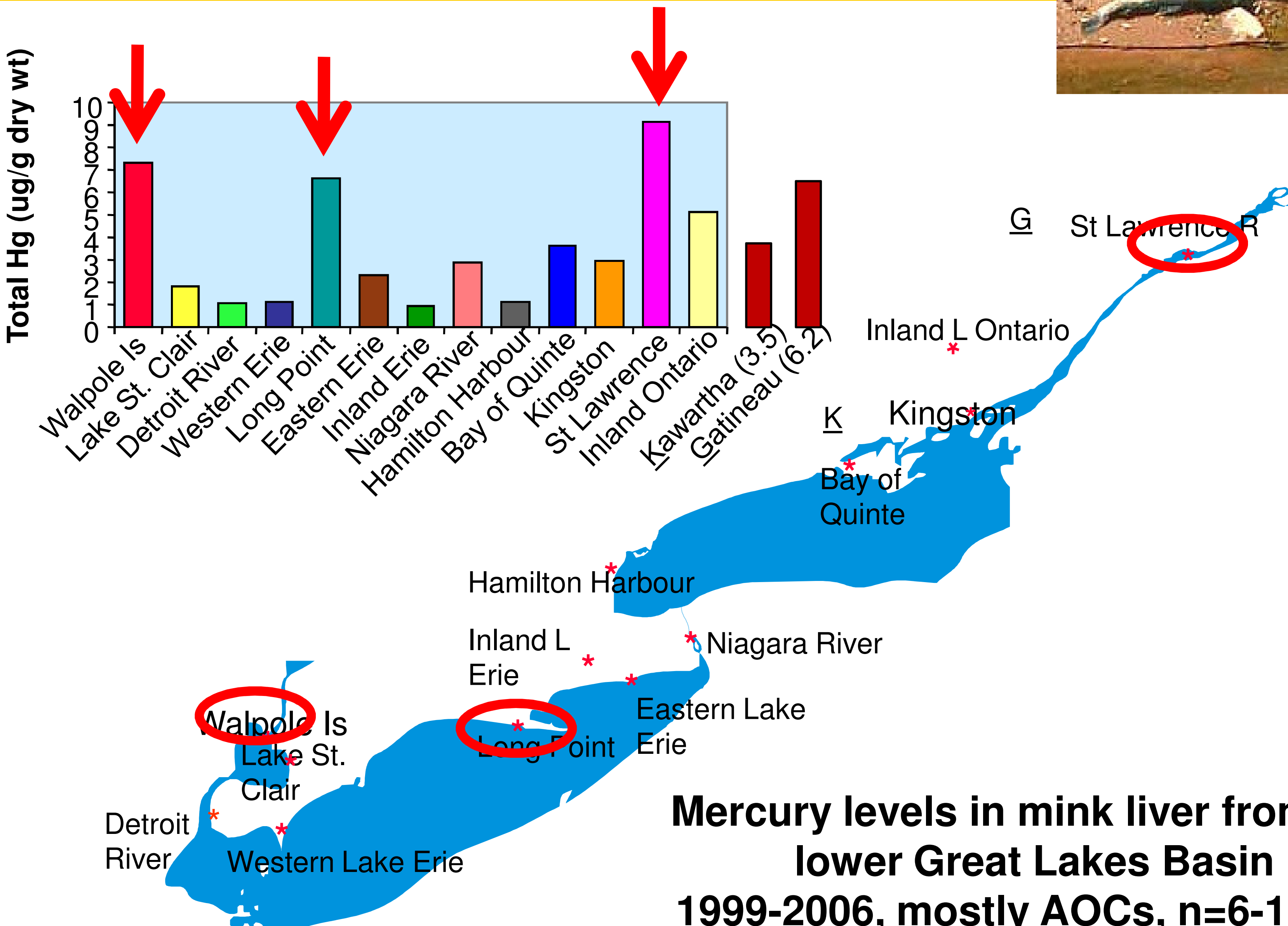
Bald Eagles as sentinels

Overall mean THg:
2.80 ppm

Overall range THg:
0.20-34.01 ppm



Mink as sentinels



Mercury levels in mink liver from the lower Great Lakes Basin 1999-2006, mostly AOCs, n=6-18/site

Credit: Pam Martin, Environment Canada

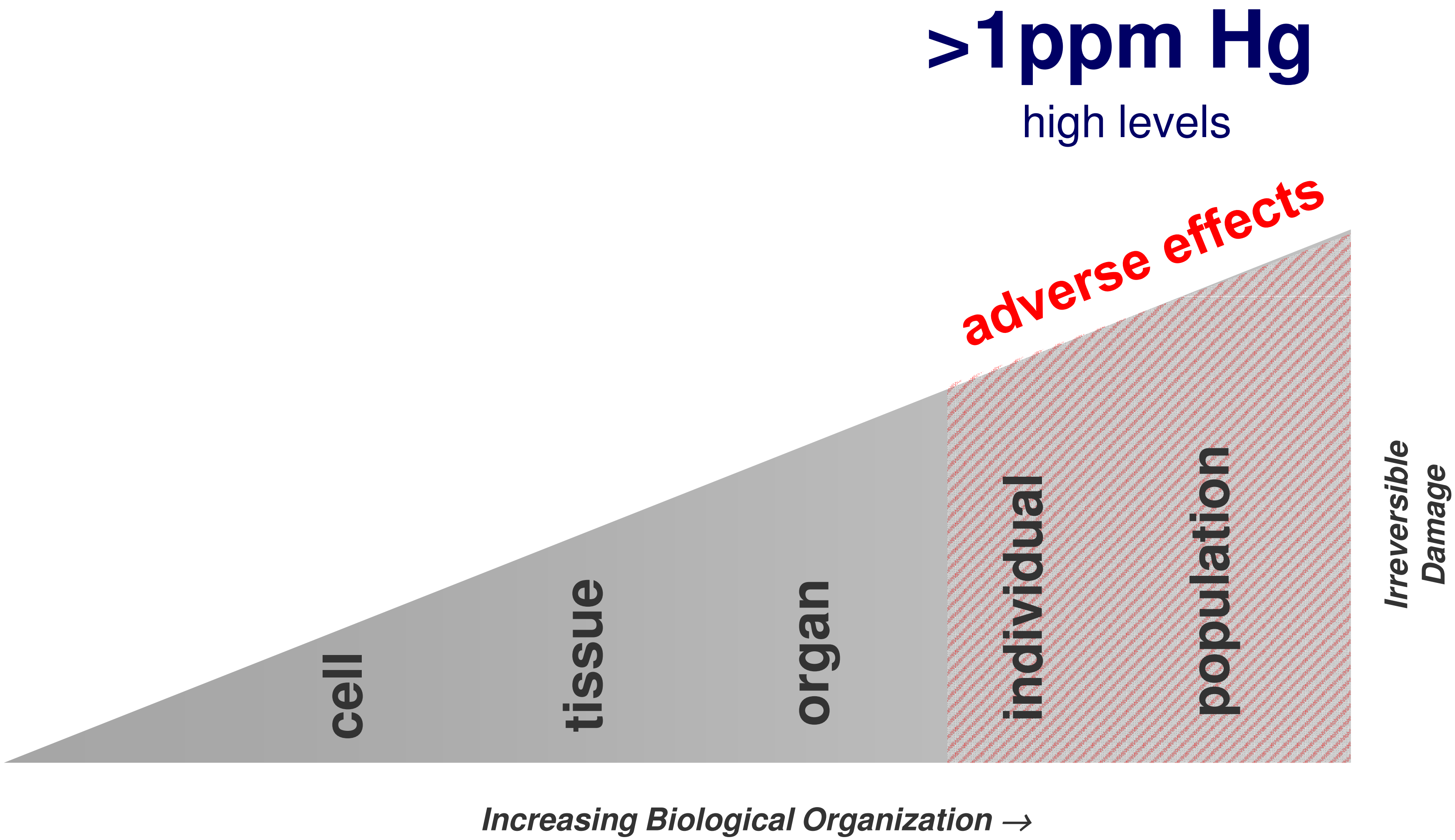
Mid-Talk Summary

- Hg levels in wildlife have decreased over time in many regions

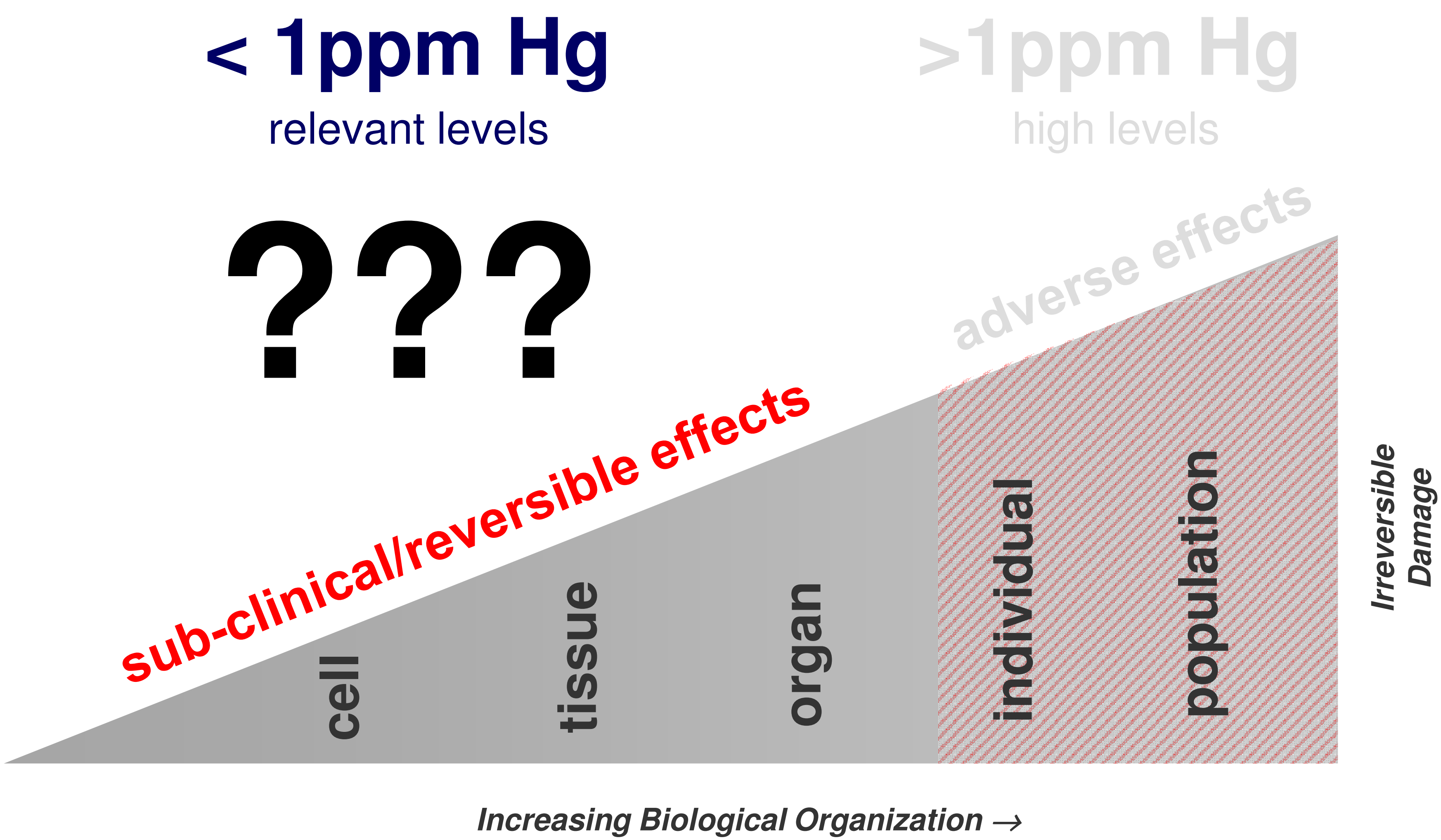
  … but levels in some species > criteria values

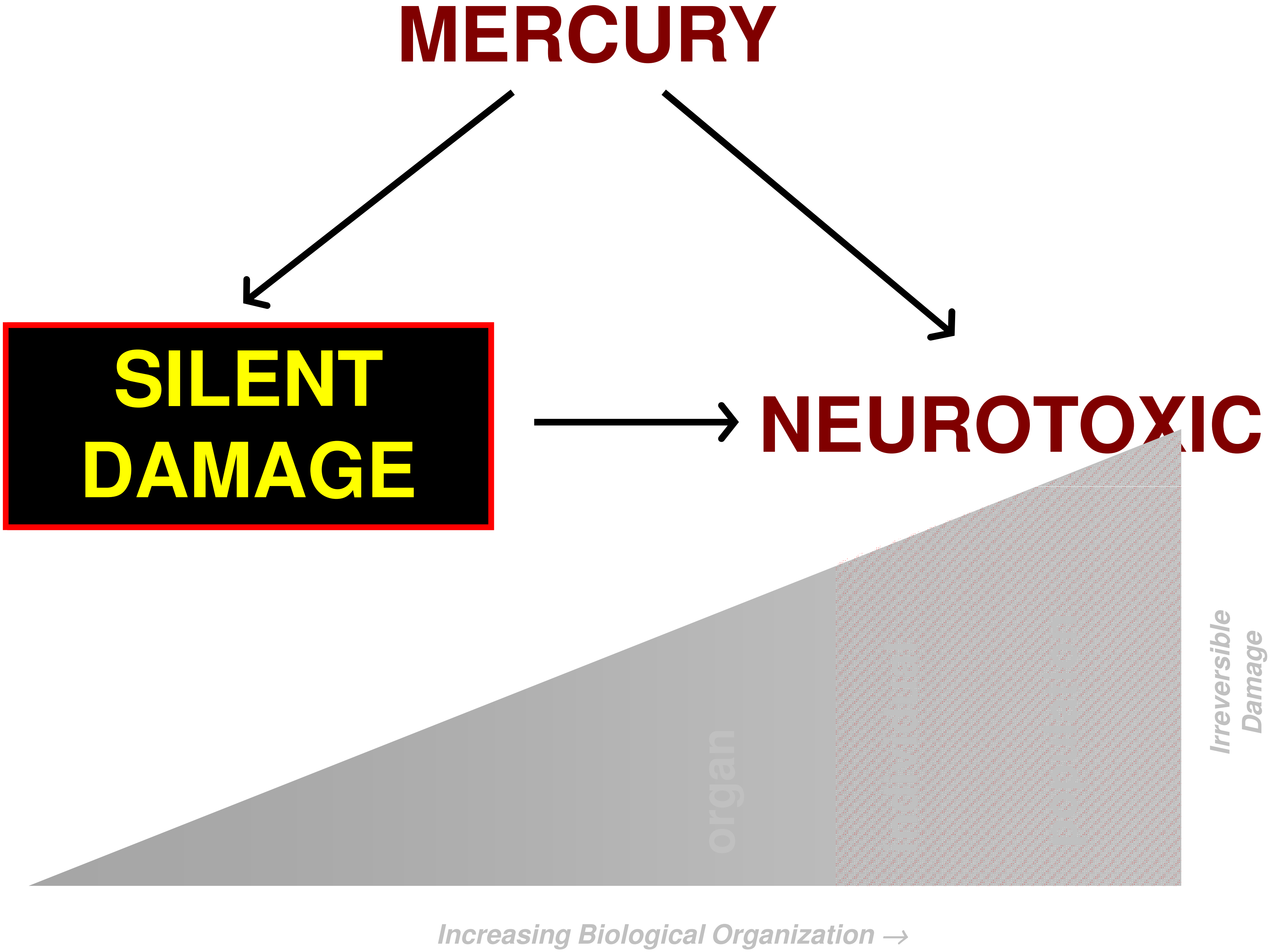
  … and hotspots still exist across Great Lakes
- data integration via GLAD Multimedia Group outputs, Ecotoxicology publications, and ICMGP meeting should increase understanding
- good at judging “exposures”; poor at assessing “harm” → Pt 2 of talk

What we know


>1ppm Hg
high levels
adverse effects
cell
tissue
organ
individual
population
Irreversible Damage
Increasing Biological Organization →

What we do not know




MERCURY
SILENT DAMAGE
NEUROTOXIC
organ
individual
population
Irreversible Damage
Increasing Biological Organization →

Silent Damage

"persistent morphological and/or biochemical injury which remains clinically unapparent unless unmasked by experimental or natural processes…

… the concept is so attractive and intuitive that one often forgets how little hard experimental data exist to directly support it."

- Kenneth R. Reuhl (1991) "Delayed expression of neurotoxicity: the problem of silent damage" Neurotoxicology 12: 341-346.

… or a "Silent Pandemic"?

"neurodevelopmental disorders caused by industrial chemicals has created a <u>silent pandemic</u> in our modern society…

…1 out of 6 children has <u>neurodevelopmental disability</u>… costs are estimated to have ranged from <u>US$110 billion to $319 billion</u> each year"

-Grandjean and Landrigan. 2006. "Developmental neurotoxicity of industrial chemicals" The Lancet 368:2167-78.

Research Hypothesis

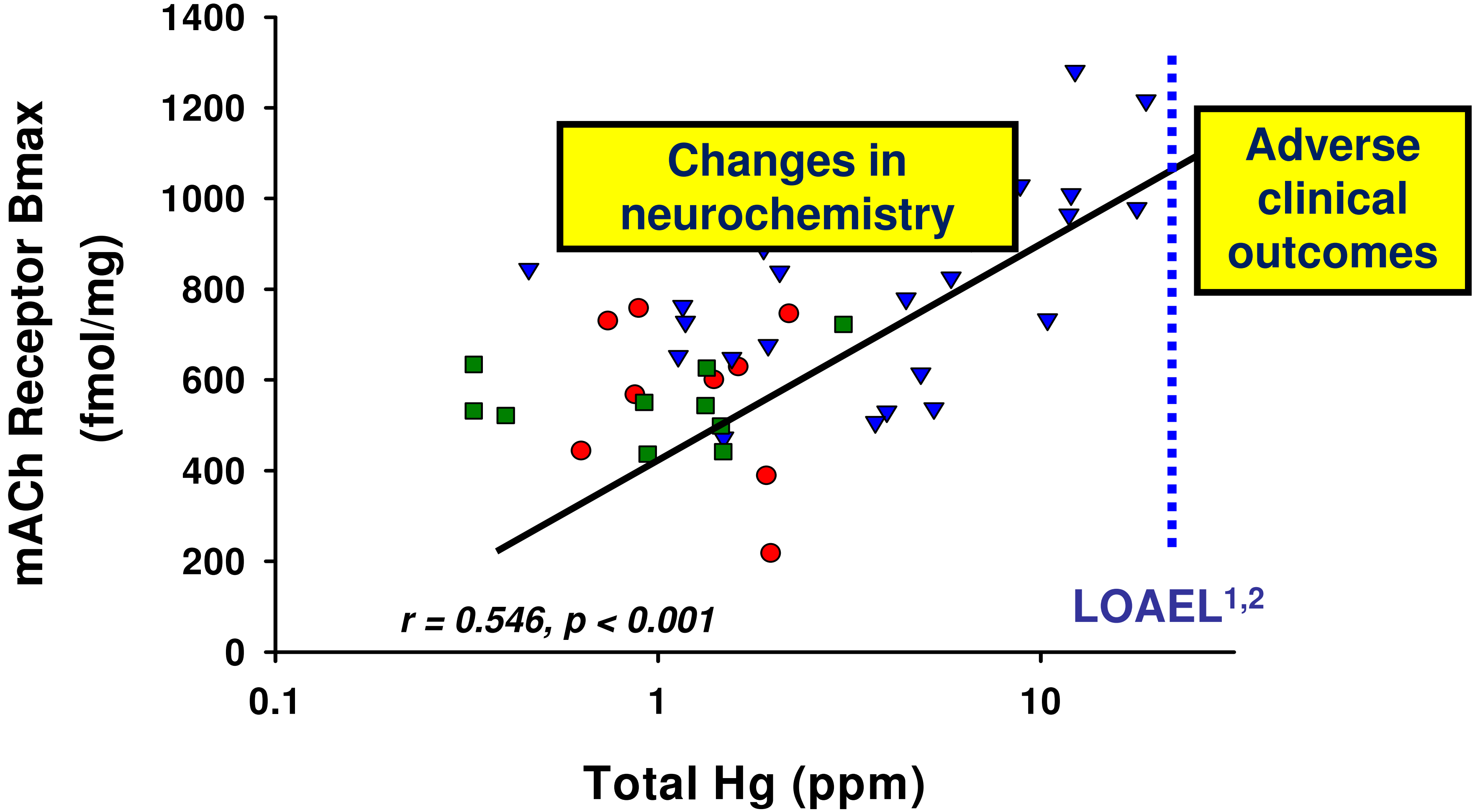
Neurochemical research can further our knowledge of the mechanisms and impacts of aquatic pollutants towards the health of humans, wildlife, and ecosystems.

Mercury → <u>BRAIN CHEMISTRY</u> → Neurotoxic

↓

objective/quantitative method to assess early/subtle effects

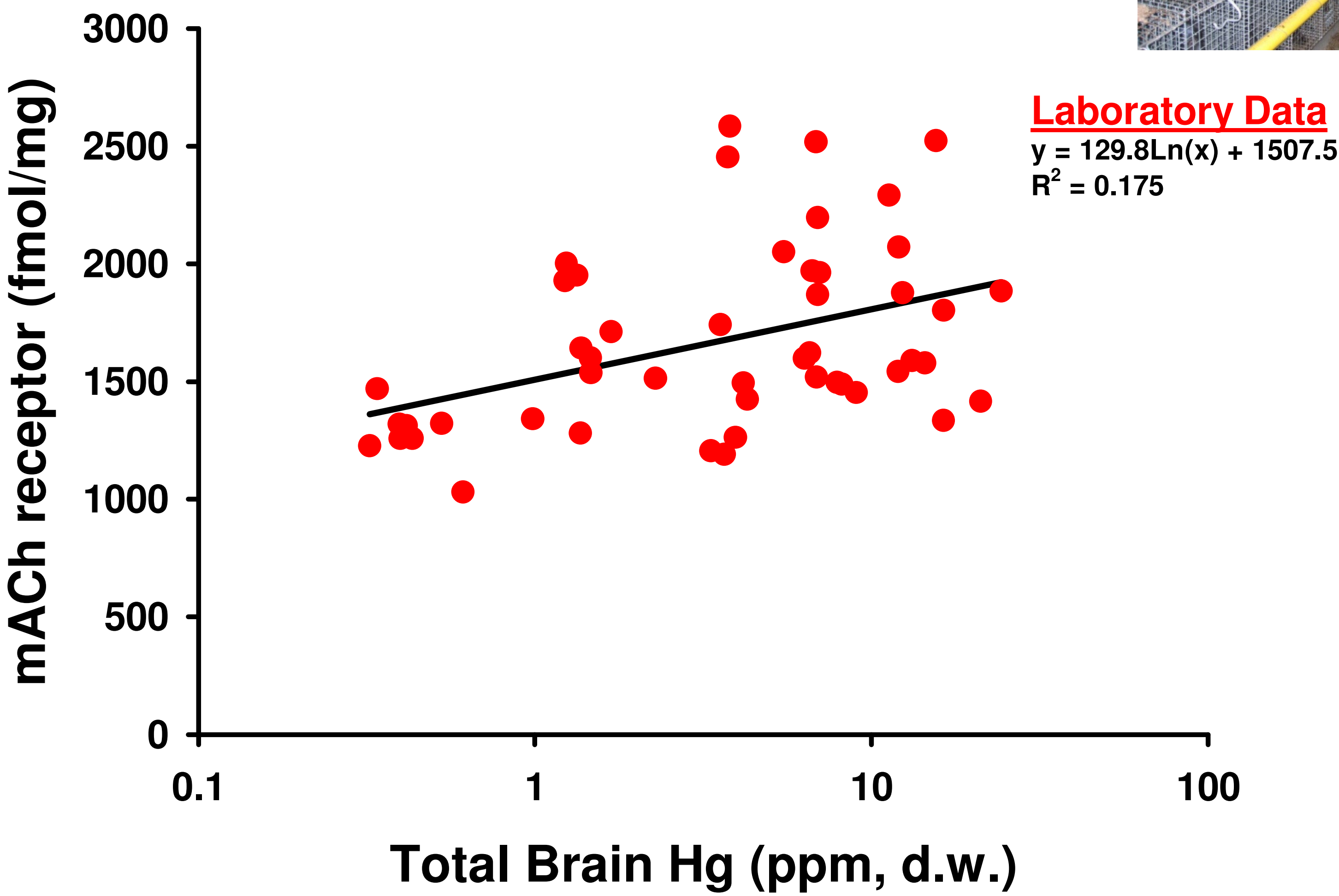
Field study –Hg α mAChR?



Environ Toxicol Chem 24: 1444-1450

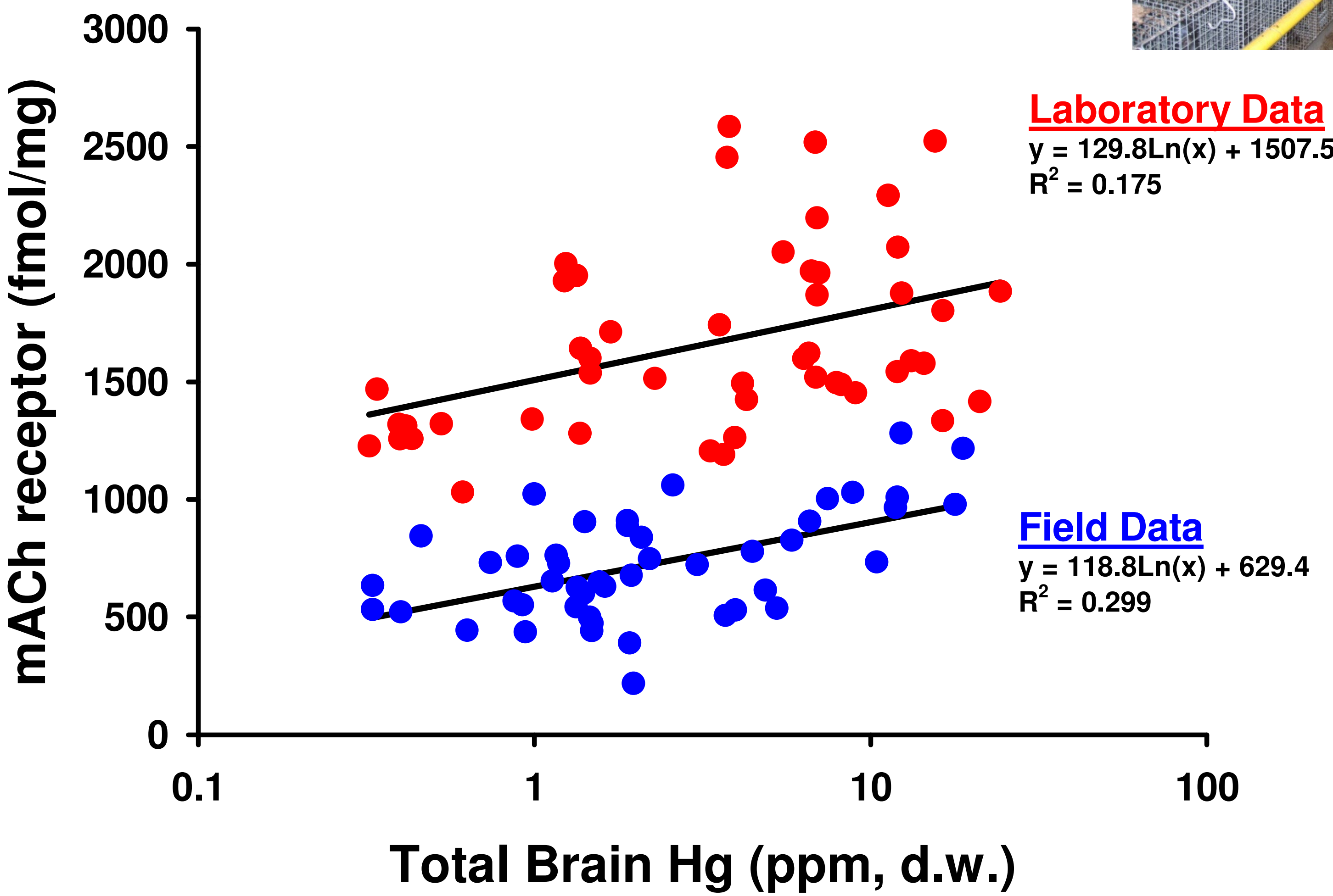
[1] Wren et al. 1987
[2] Wobesor et al. 1976

Lab study – corroboration?



Toxicological Sciences 91: 202-209

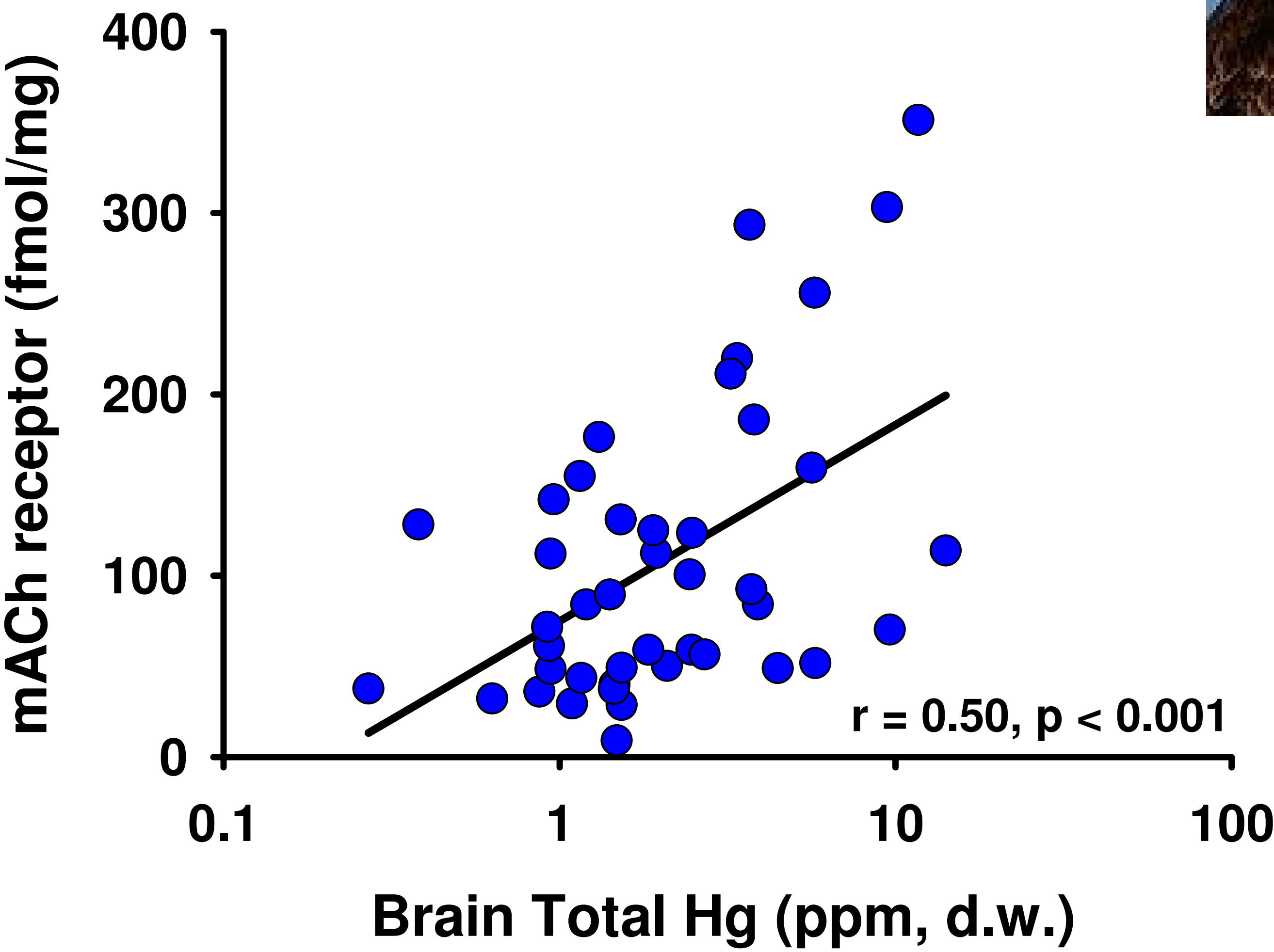
Lab study – corroboration?



SIMILAR SLOPE-RESPONSE RELATIONSHIPS

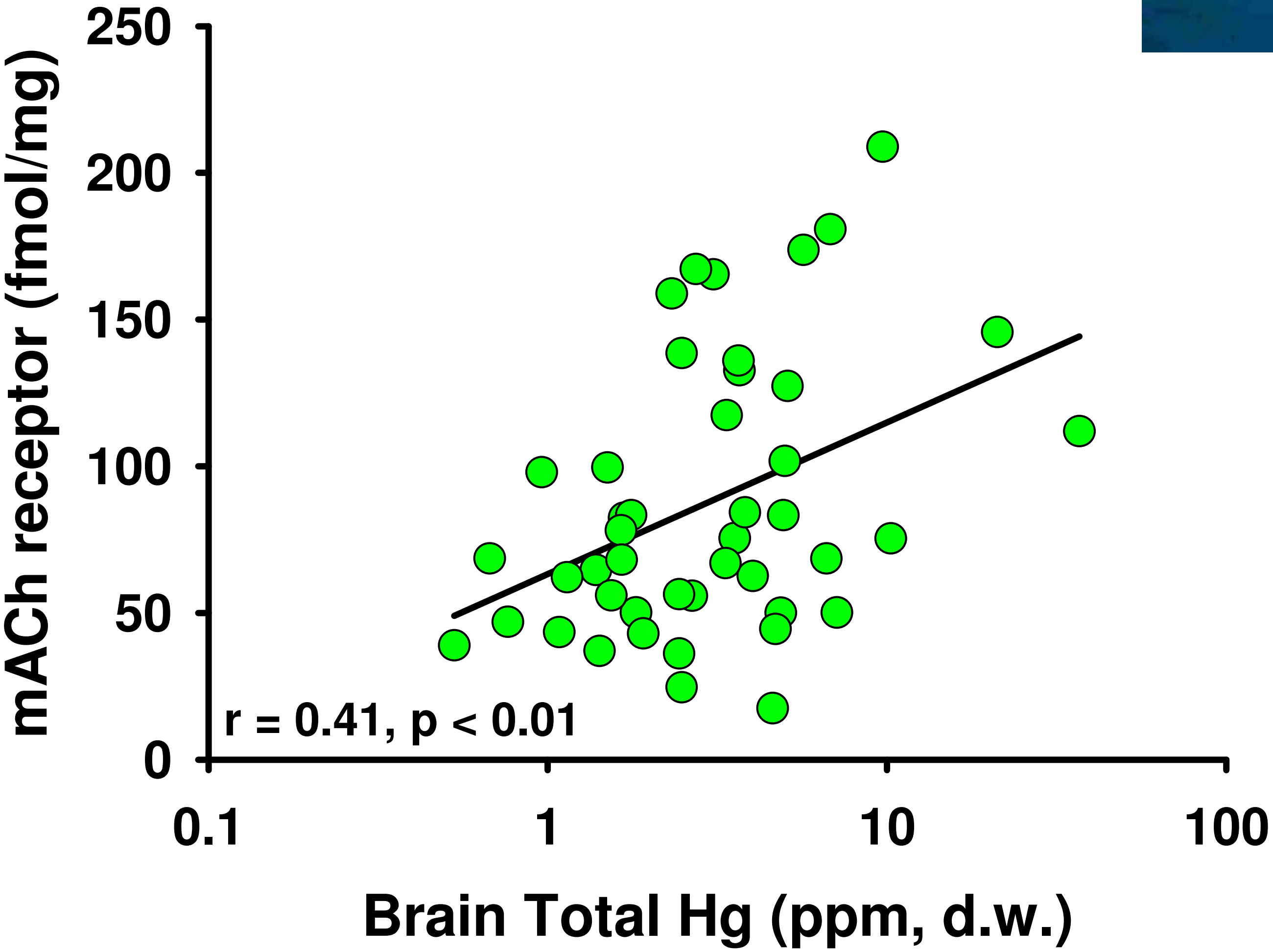
Toxicological Sciences 91: 202-209

Hg & mAChR: BALD EAGLE



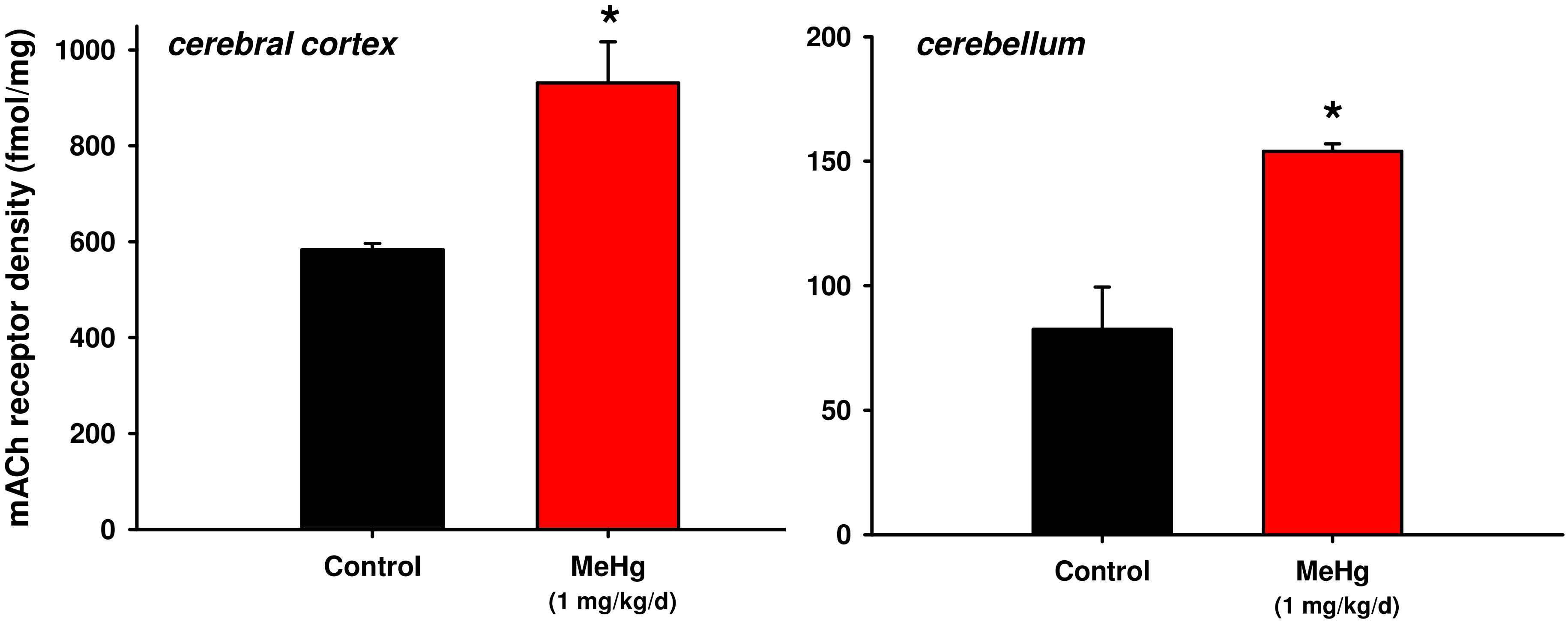
Ecotoxicology 17: 93-101

Hg & mAChR: COMMON LOON



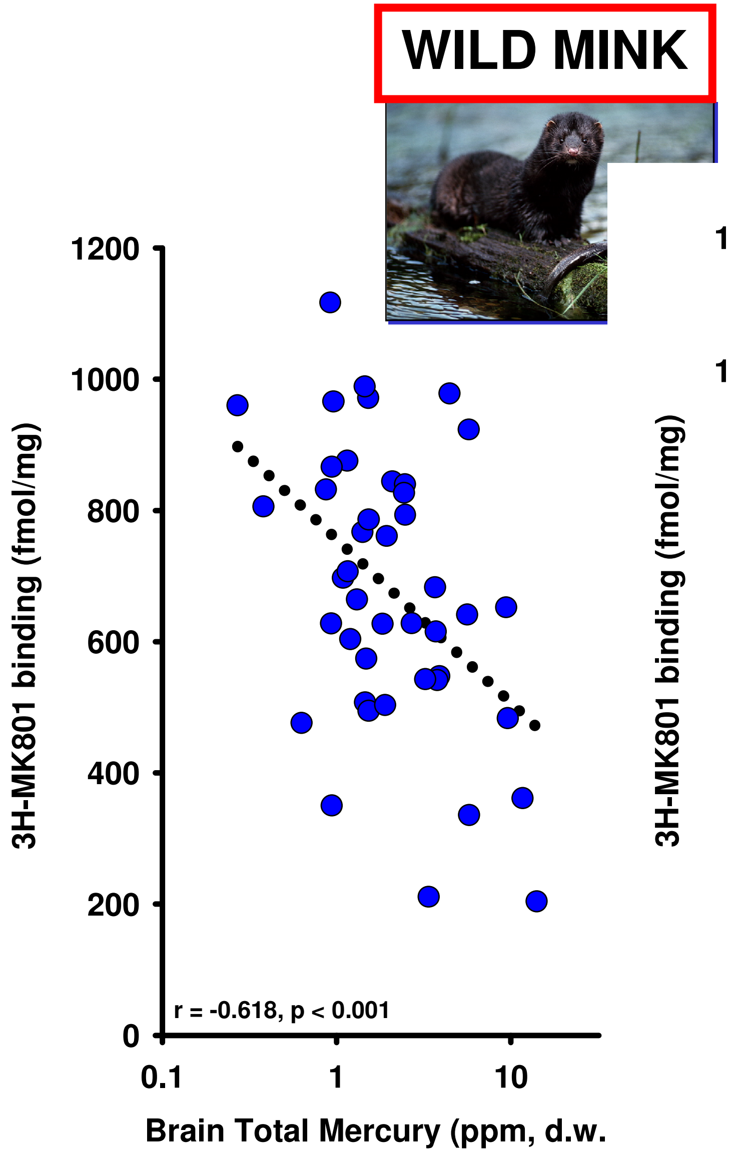
Ecotoxicology 17: 93-101

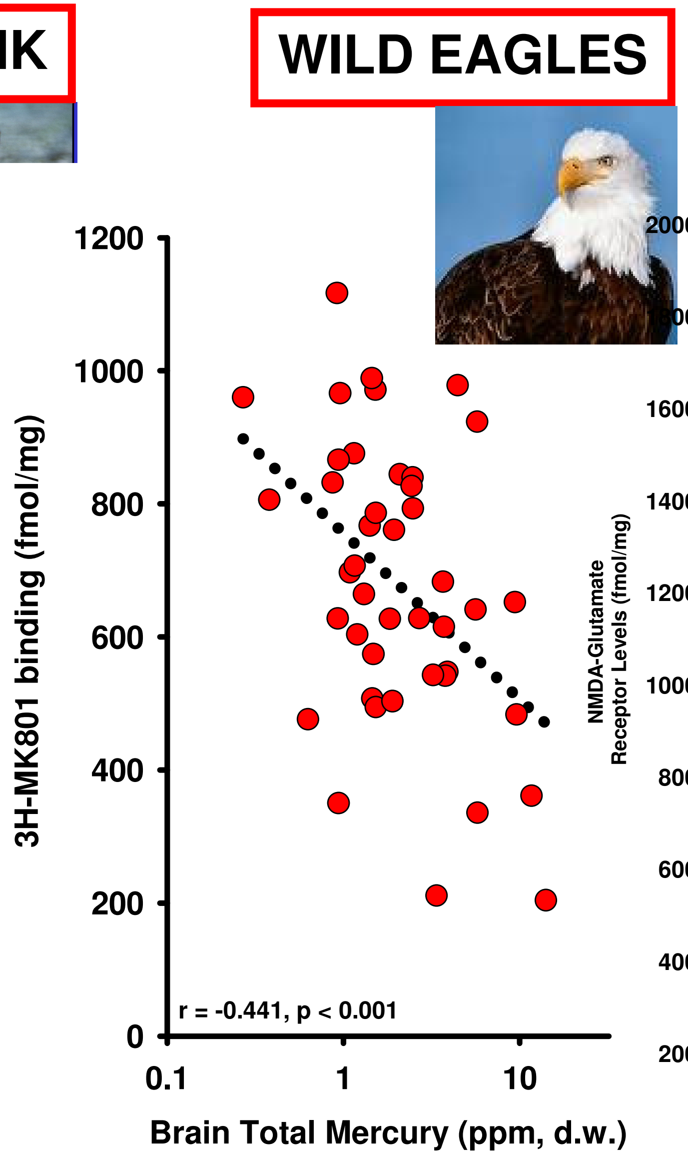
Hg & mAChR: LAB RAT

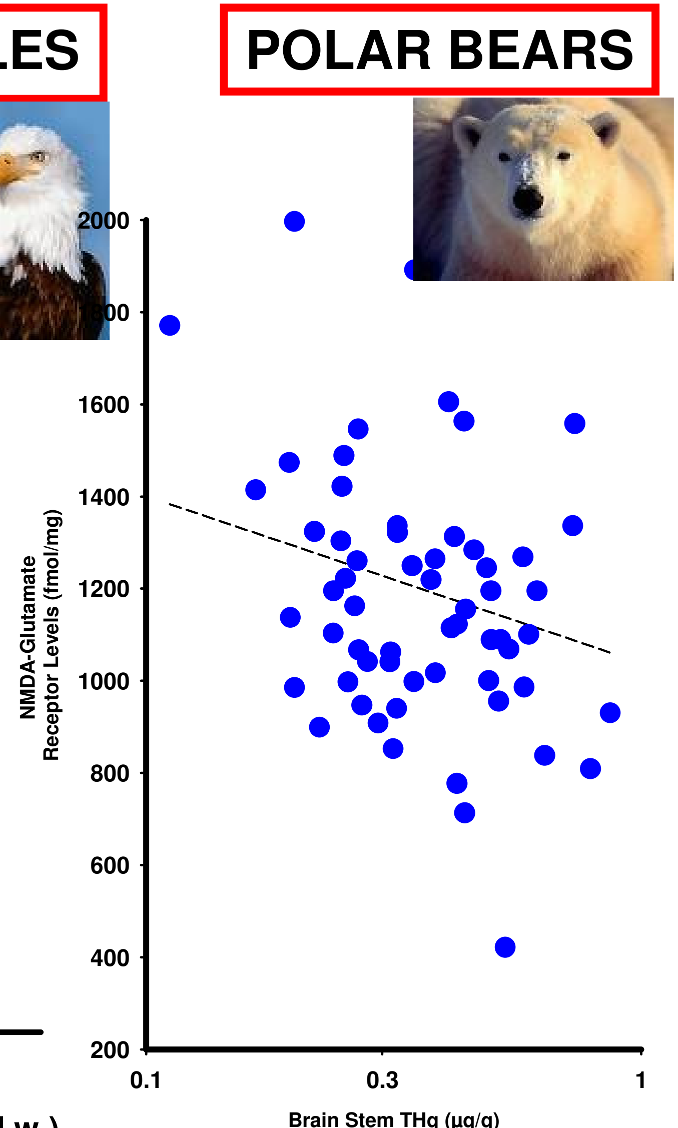


Coccini et al., 2006. Neurotoxicology. 27: 468-477

Hg and NMDA-glutamate receptors





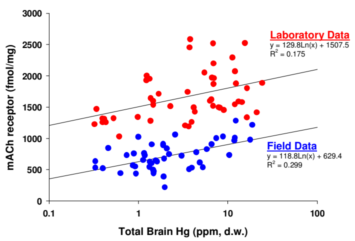


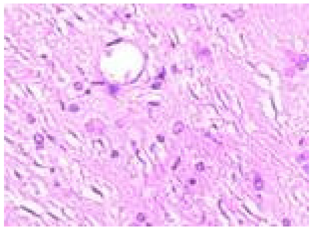
Ecologically Relevant Levels of Hg, especially in the Great Lakes region

Historic and High Exposure Levels

Uptake **Neurochemical Effects** **Lesions**[1,2] **Behaviour**[1,2]

0 **0.1** **0.5** **1** **2** ***[Dietary] ppm***





Toxicol Sci 91: 202-209
Environ Toxicol Chem 24: 1444-1450
Environ Sci Technol 39: 3585-3591

[1] *Wren et al. 1987*
[2] *Wobesor et al. 1976*

<u>1956</u>:
first case of human Minamata disease (mercury poisoning) reported in Japan

<u>1951</u>:
"*citizens noticed that many of the town's cats, rats, crows, and fish behaved strangely. For no apparent reason they exhibited frenzied behavior, throwing themselves against stone walls, staggering as though intoxicated, and frequently hurling themselves into Minamata Bay, where many drowned.*"

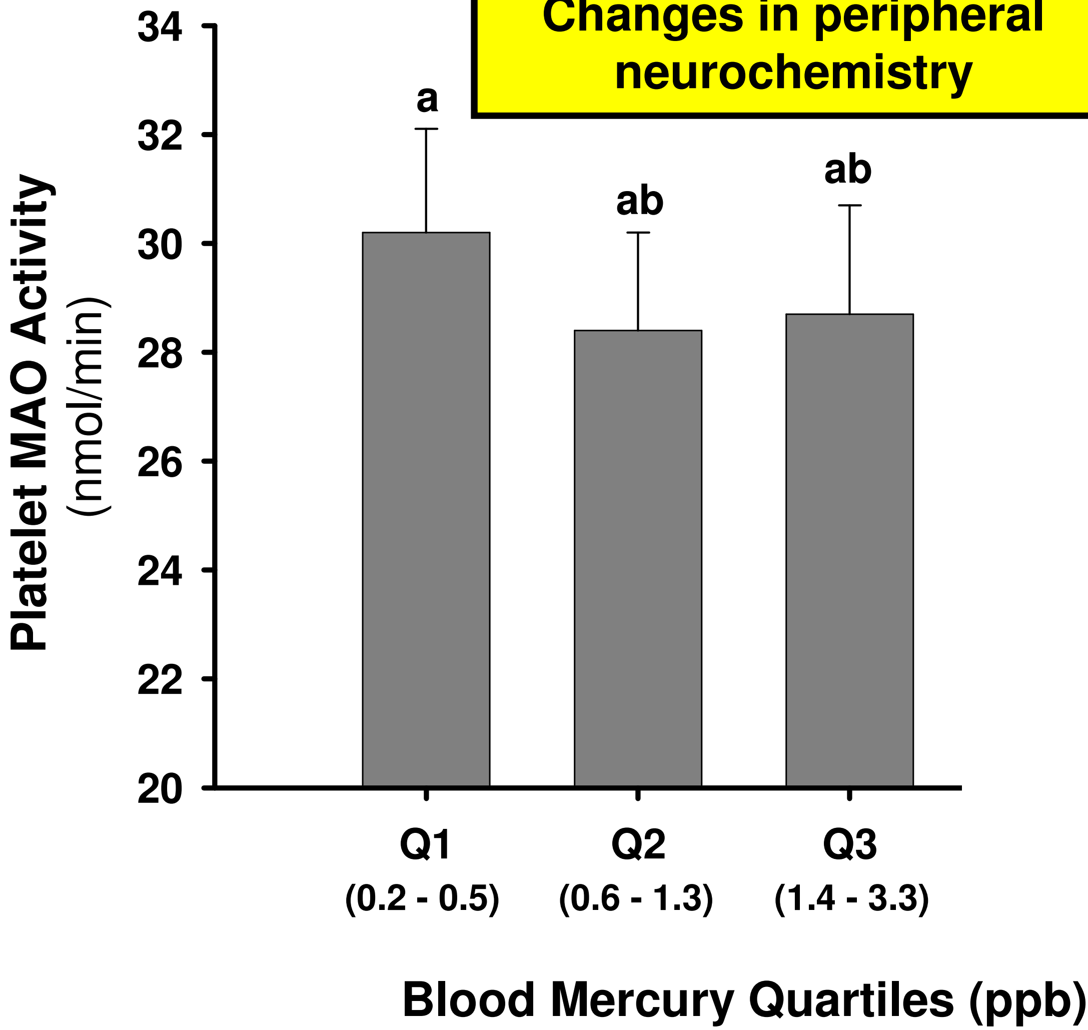
Harada, 1995. Crit Rev Toxicol 25:1
Eto, 1997. Toxicol Pathol 25:614
Aronson, 2005. Med Health RI 88:209

“In ecoepidemiology, the occurrence of an association in more than one species and species population is very strong evidence for causation.”

Glen Fox. 1991. J Toxicol Environ Health 33: 359-373

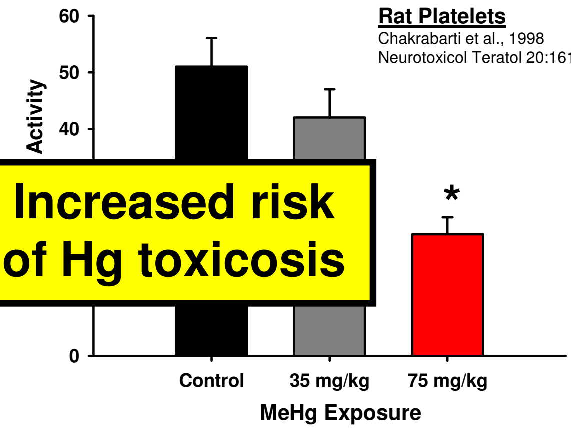
“our fate is connected with the animals.”

Rachel Carson. 1962. Silent Spring

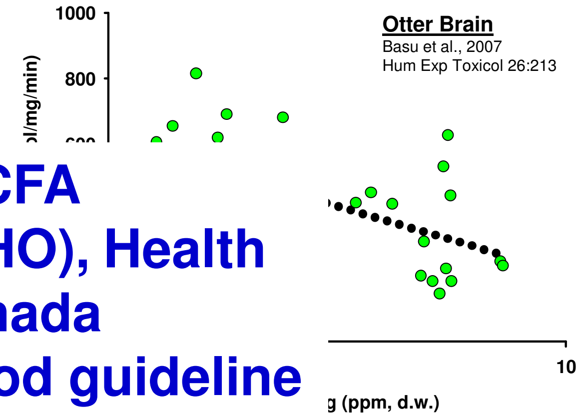


Changes in peripheral neurochemistry

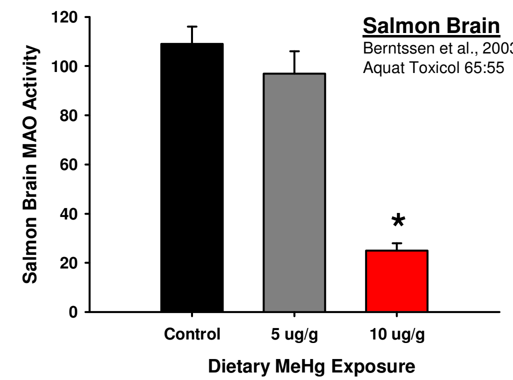
Neurotoxicology 27: 429-436



Increased risk of Hg toxicosis



JECFA (WHO), Health Canada blood guideline > 20 ppb



Final Summary

- Pt 1. Piscivorous wildlife as sentinels of mercury exposure (spatial, temporal)
- Pt 2. Neurochemical biomarkers provide mechanistic link between exposure & disease
- Continuum of effects established, with real-world levels α neurochemical change
- Multiple neurochemical pathways and brain regions tease apart toxicant-specific impacts and physiological/ecological relevance

Funding & Collaborators

A) GLAD-sponsored Multimedia Mercury Measurements Workshop --- WILDLIFE Team

-Nil Basu and Mike Meyer (co-leaders); Members: Dave Evers, Kevin Kenow, Sean Strom, Bill Route, Chip Weseloh, Pam Martin, Tony Scheuhammer, Tom Custer, Mike Wierda, Bill Bowerman, Madeline Turnquist

B) GLAD-sponsored "Neurochemical Biomarkers in Wildlife" grant

-Nil Basu (PI); Key Collaborators: Sean Strom (Wisc DNR), Bill Route (NPS), Tom Cooley(MI DNR), Dennis Bush(MI DNR), Kay Neuman (SOAR), Mike Meyer (Wisc DNR), Irene Bueno (Raptor Center), Ling Shen (Minn DNR), Dave Sherman (OH DNR); Students at Michigan: Dong-Ha Nam, Jennifer Rutkiewicz, Peter Dornbos

C) University of Michigan School of Public Health Dean's Office

Questions?

NIL BASU, PhD

Assistant Professor
Department of Environmental Health Sciences
School of Public Health, University of Michigan
Ann Arbor, MI

niladri@umich.edu
sitemaker.umich.edu/ecotoxicology.lab