Exposure and effects of mercury on terrestrial wildlife





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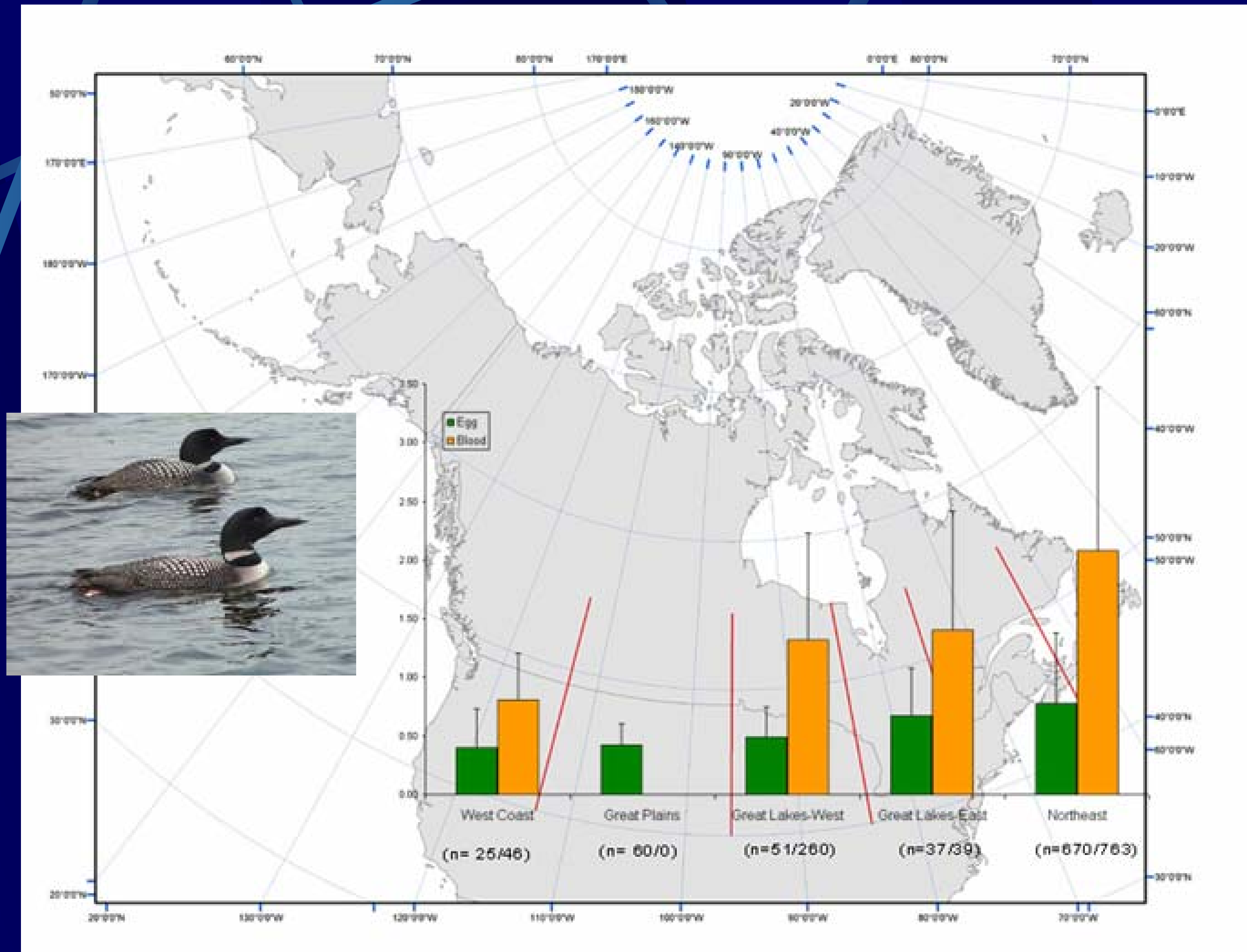
Presentation Outline

1. Understanding the where, what, why of biotic Hg
   - Geographic context
   - Factors related to Hg interpretation
2. Developing national monitoring standards
   - Potential national indicator species
   - Why use the loon?
3. Risk Characterization (weight of evidence approach)
   - Exposure profile results (spatially explicit)
   - Hazard profile results (individual & population level)
4. Linking science to policy
   - WCV Hg Model
   - Southeastern NH “hotspot”
5. What’s next?

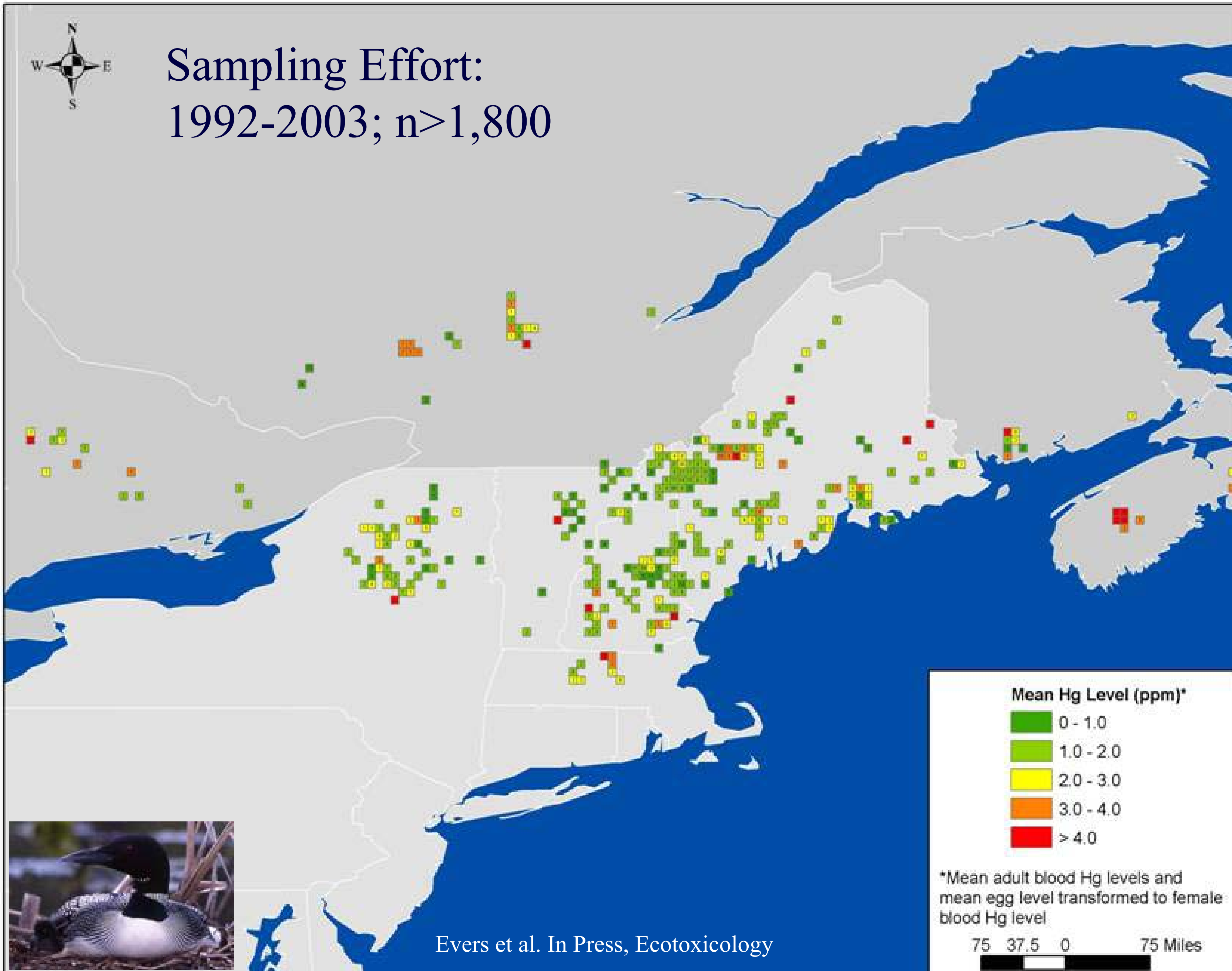
What parts of the country are at greatest risk?

Geographic trend of Hg in a standard species: Common Loon (n>2000 individuals)*



*Evers et al. 1998, Environ. Tox. Chem.; Evers et al. 2003, Ecotoxicology

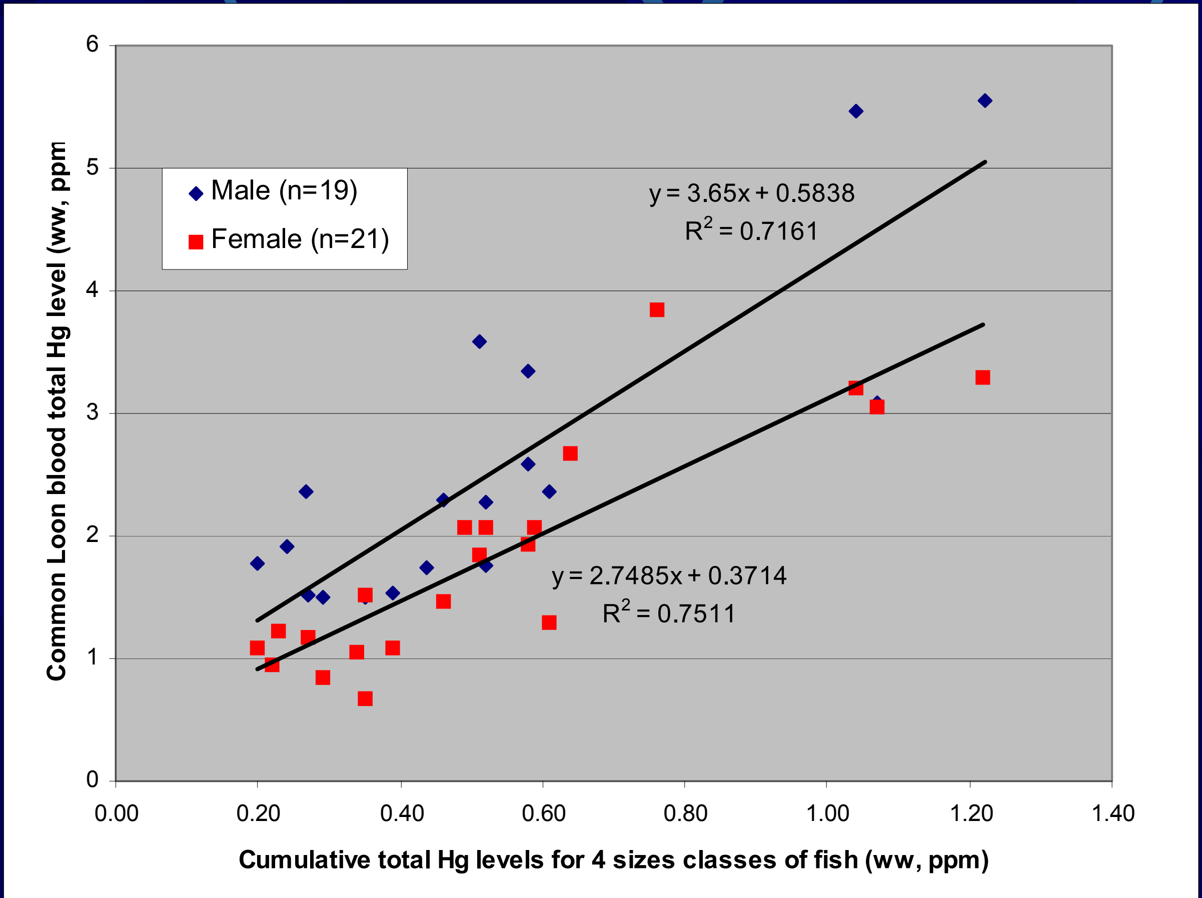
How is MeHg availability distributed within the Northeast?



N
W
E
S
Sampling Effort:
1992-2003; n>1,800
Mean Hg Level (ppm)*
0 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 4.0
> 4.0
*Mean adult blood Hg levels and mean egg level transformed to female blood Hg level
75 37.5 0 75 Miles
Evers et al. In Press, Ecotoxicology

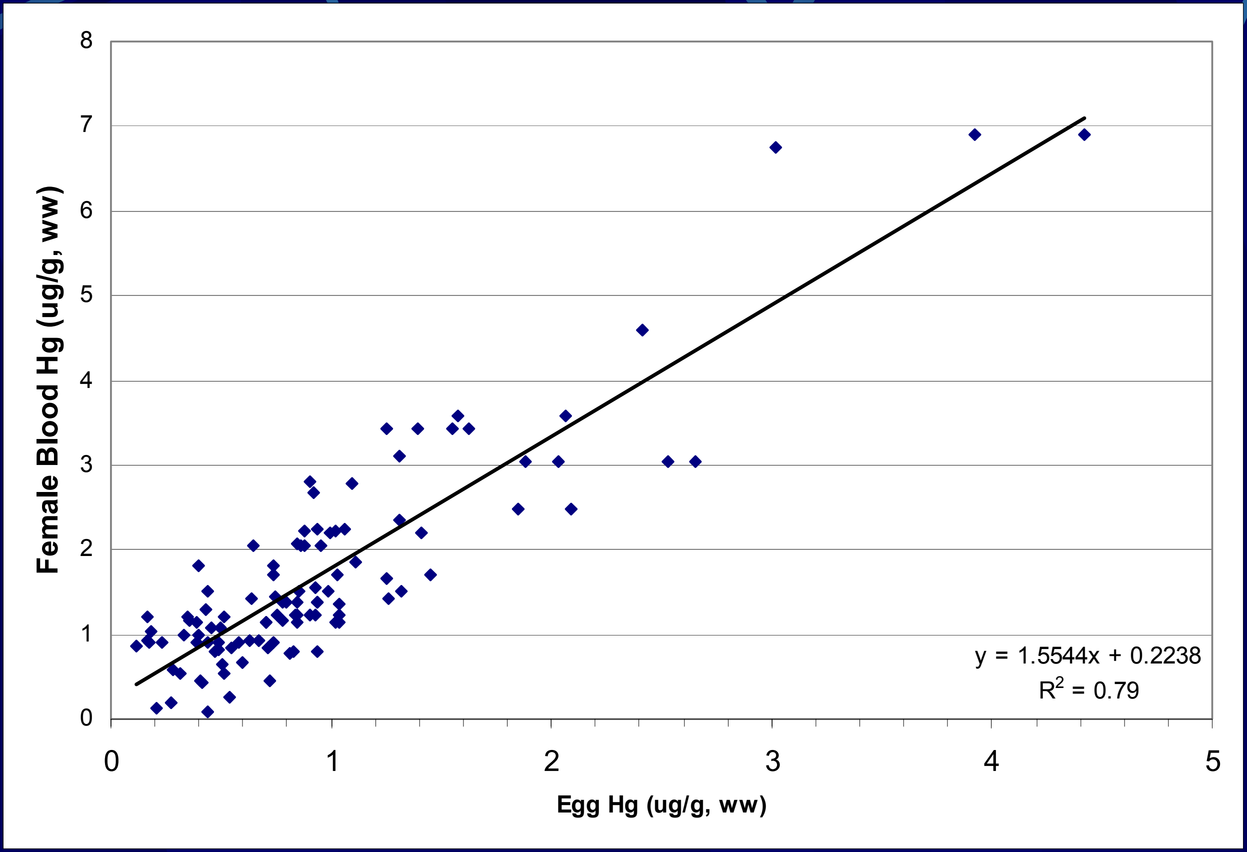
What do tissues indicate?

Fish prey Hg strongly correlates with adult loon blood Hg (r2>0.72)*



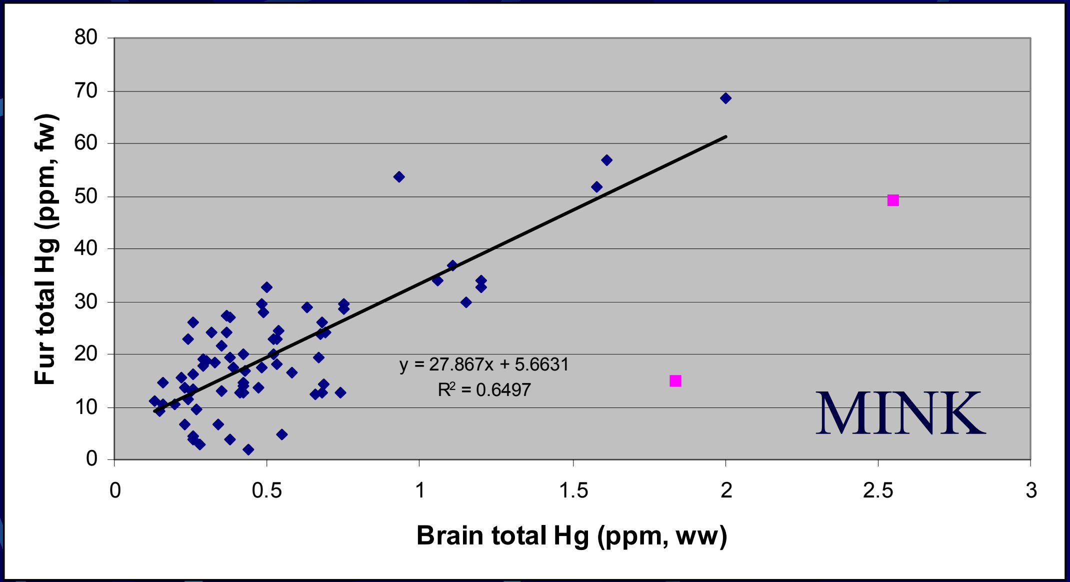
* Scheuhammer and Blancher 1998, Hydrobiologia; Burgess and Hobson In Press. Hydrobiologia; Evers et al. In Press, Ecotoxicology

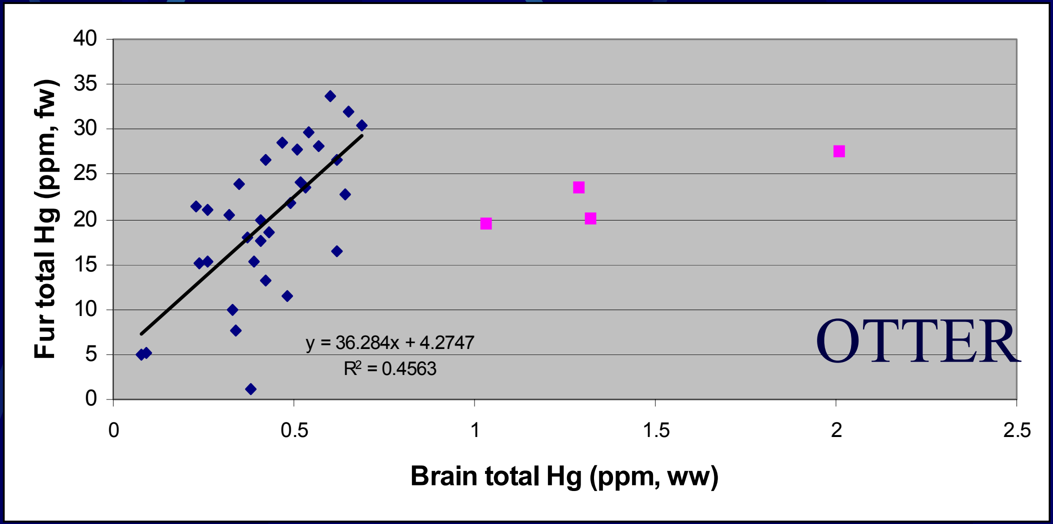
Loon egg Hg strongly correlates with adult female blood Hg (r^2=0.79)*



* Evers et al. 2002. Ecotoxicology 12:69-81.

Otter and mink fur Hg strongly correlates with brain (and liver) Hg*





* Yates et al. In Press, Ecotoxicology

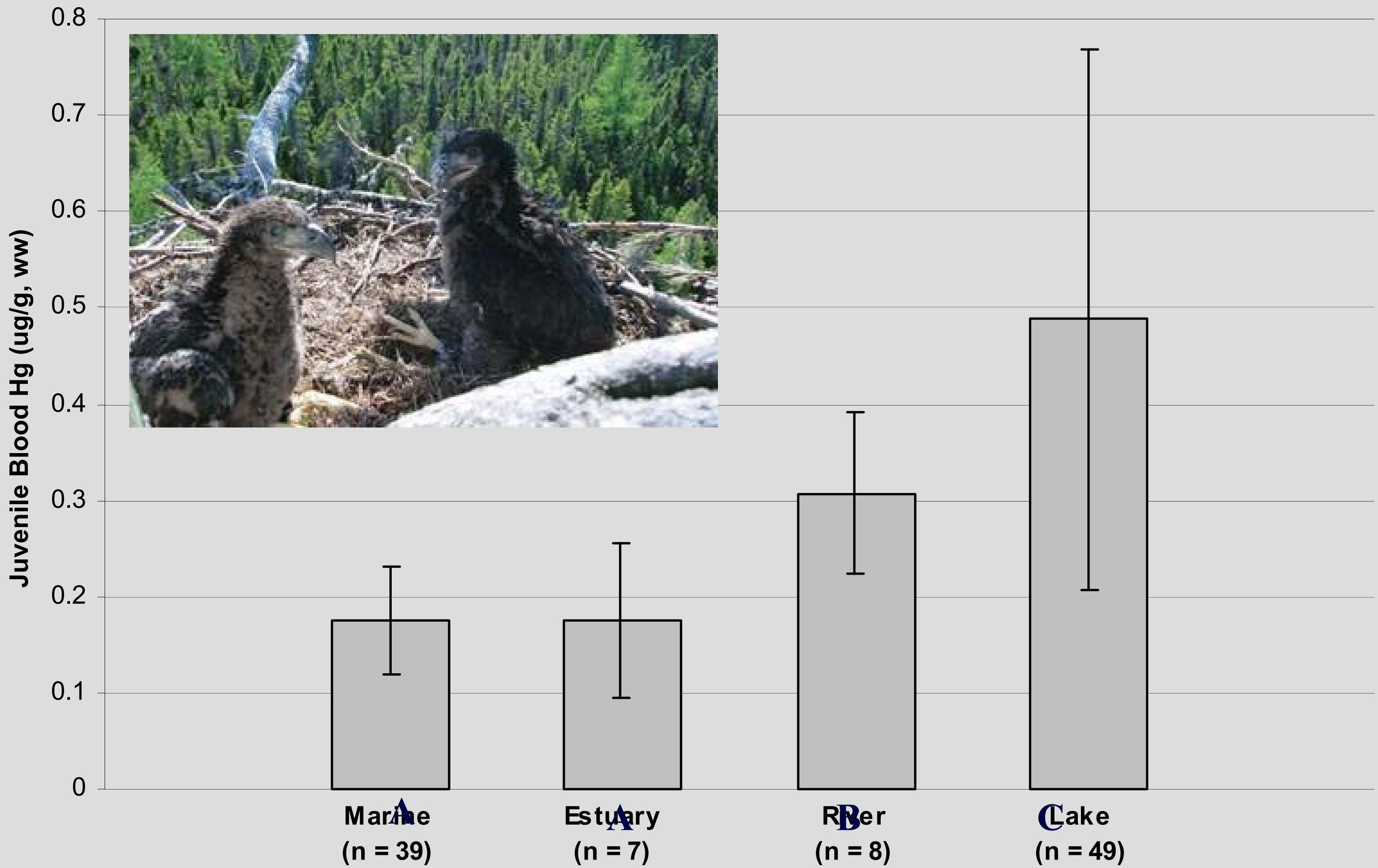
What habitats are at greatest risk to higher trophic level biota?

1. Aquatic systems
   - Wetlands, particularly bogs
   - Acidic lakes (<6.3)*
   - Certain reservoirs (current USDA study)
   - Urban estuaries (current USFWS study)

2. Terrestrial systems
   - Mountaintops~
   - Areas deficient in Ca (due to potential synergy)

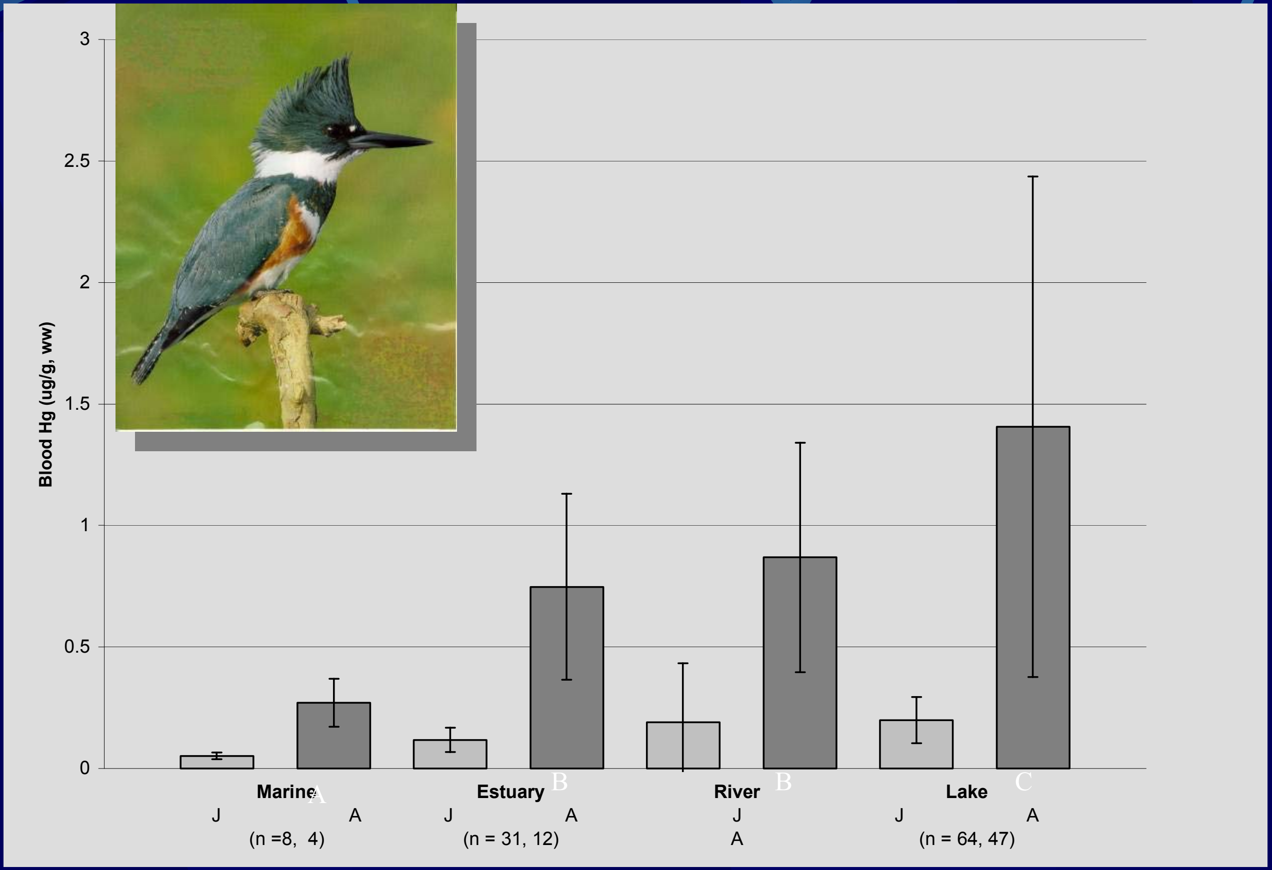
*Meyer et al. 1995, Hydrobiologia
~ Rimmer et al. In Press, Ecotoxicology

Blood Hg levels in juvenile Bald Eagles, Maine



Evers et al. In Press, Ecotoxicology

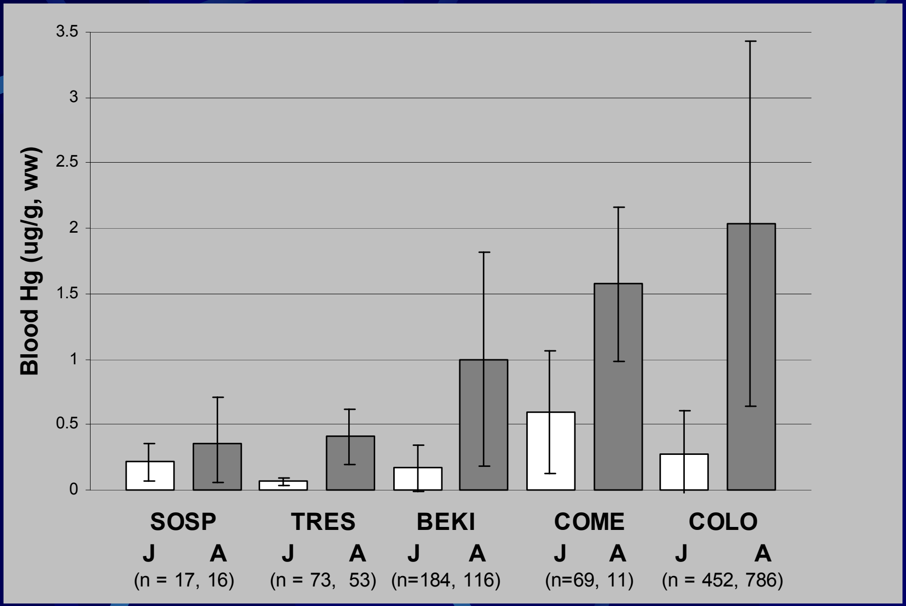
Blood Hg levels in adult and juvenile Belted Kingfishers, Maine



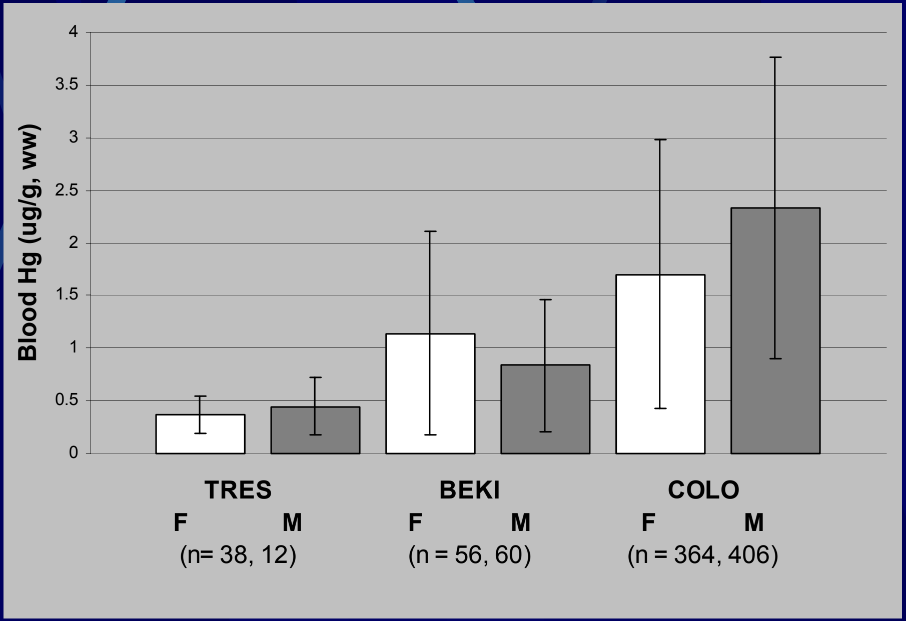
Evers et al. In Press, Ecotoxicology

Factors confounding interpretation of Hg exposure

Age Class

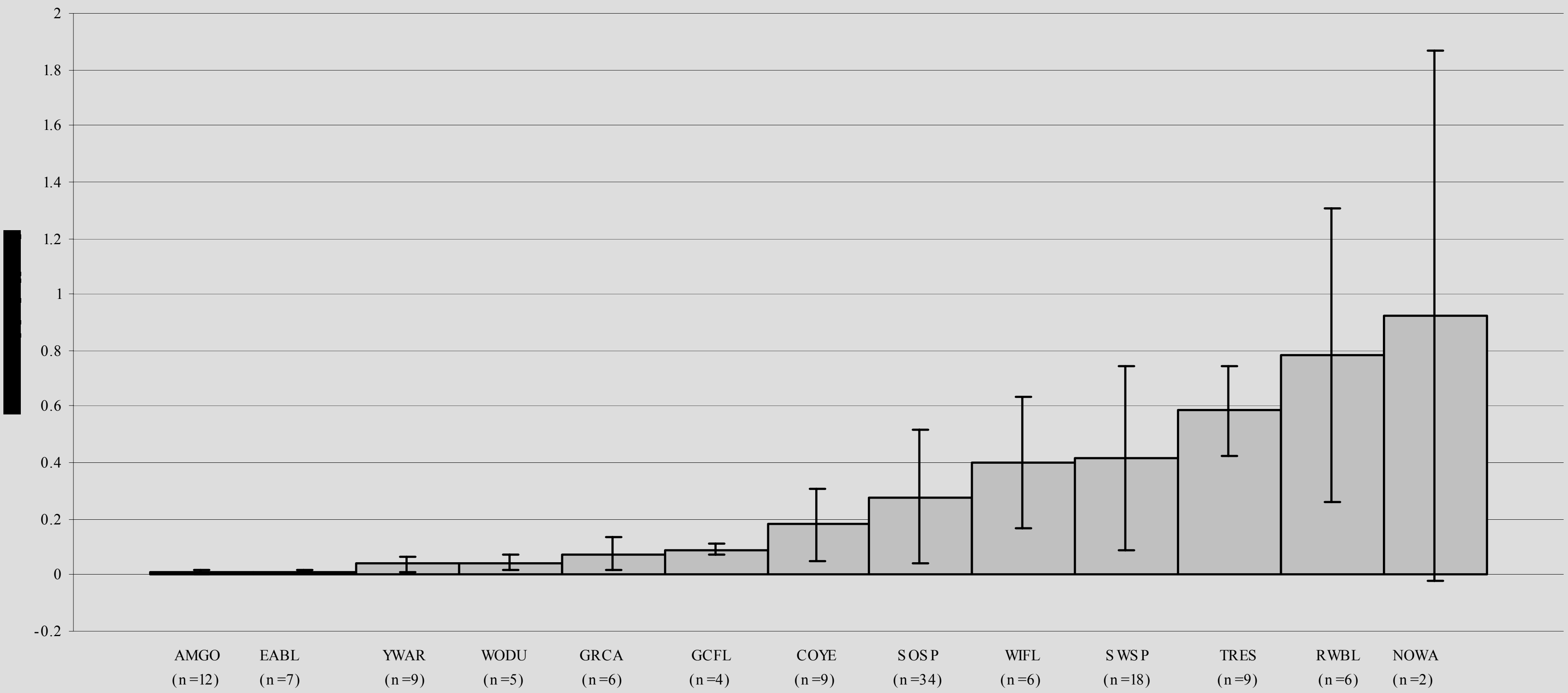


Sex

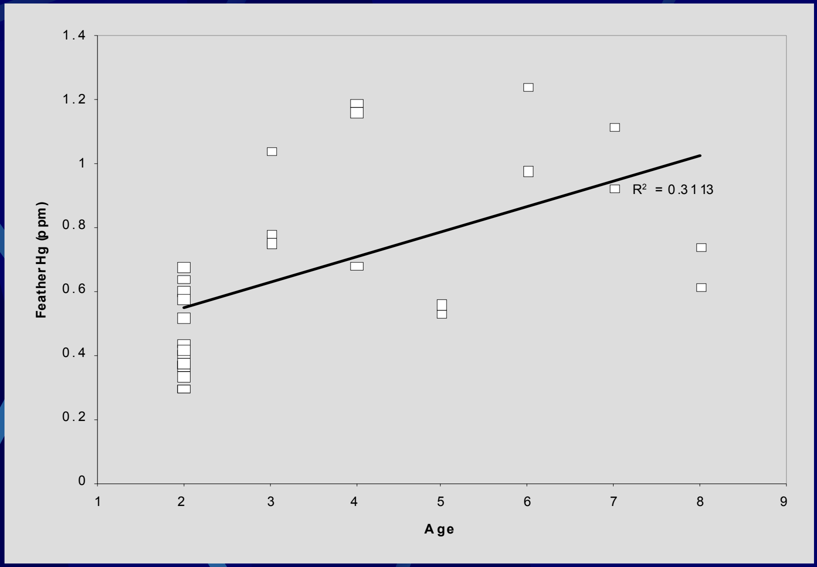


Evers et al. In Press, Ecotoxicology

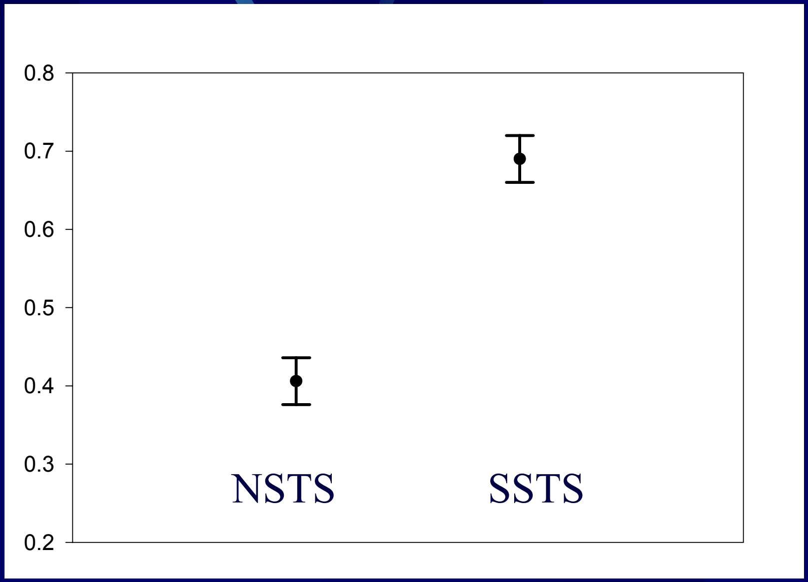
Insectivorous songbird blood Hg level comparison



Mountains (ug/g, ww)*
New England: 0.08-0.27
DR and Cuba: 0.03-0.42



Urban Estuaries~
Blood Hg (ug/g, ww)
5 locations, southern ME



*Rimmer et al. In Press, Ecotoxicology
~Shriver et al. 2002, MDEP Unpubl. Rept.

What is the standard measuring stick?

National indicators program*

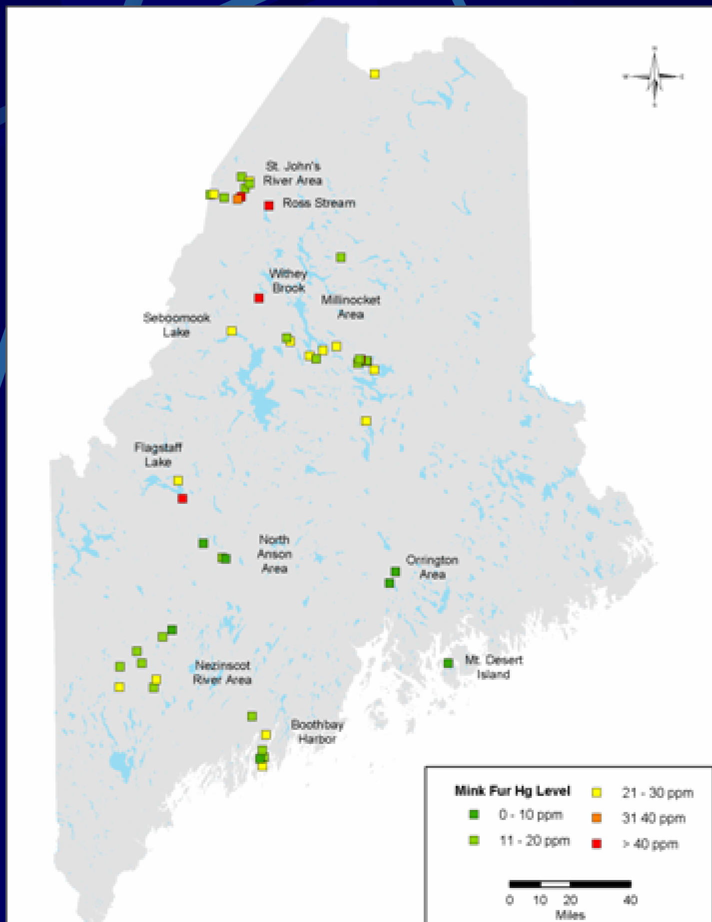
National EPA-directed and cooperative process is currently targeting candidate species, based on (1) available information, (2) geographic representation, (3) at greatest risk, (4) logistical feasibility and (5) most interpretative of site (i.e., predictable feeding area/small home range).

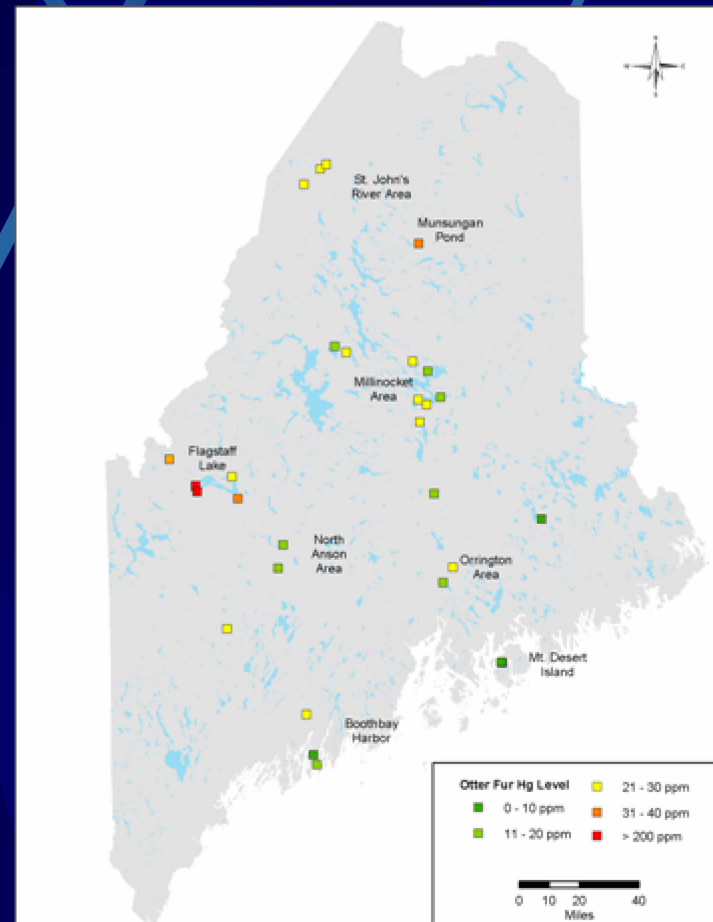
Candidate Indicators:

Lakes….	Common Loon & Bald Eagle
Rivers….	Belted Kingfisher
Mountains…	Bicknell's Thrush
Wetlands…..	Tree Swallow
Estuaries…..	saltmarsh sparrows (SSTS, NSTS, SESP)
Inshore marine areas..	Common Tern
Offshore marine areas..	Leach's Storm-Petrel

* Mason et al. In press. Environmental Science and Technology 39 & Wolfe et al. In press. SETAC book.

Mink and River Otter as indicators of landscape level risk*





Yates et al. In Press, Ecotoxicology

The Common Loon as a national indicator:

(1) monitoring exposure,
(2) determining effects, &
(3) relating at a population level

Why the Common Loon?

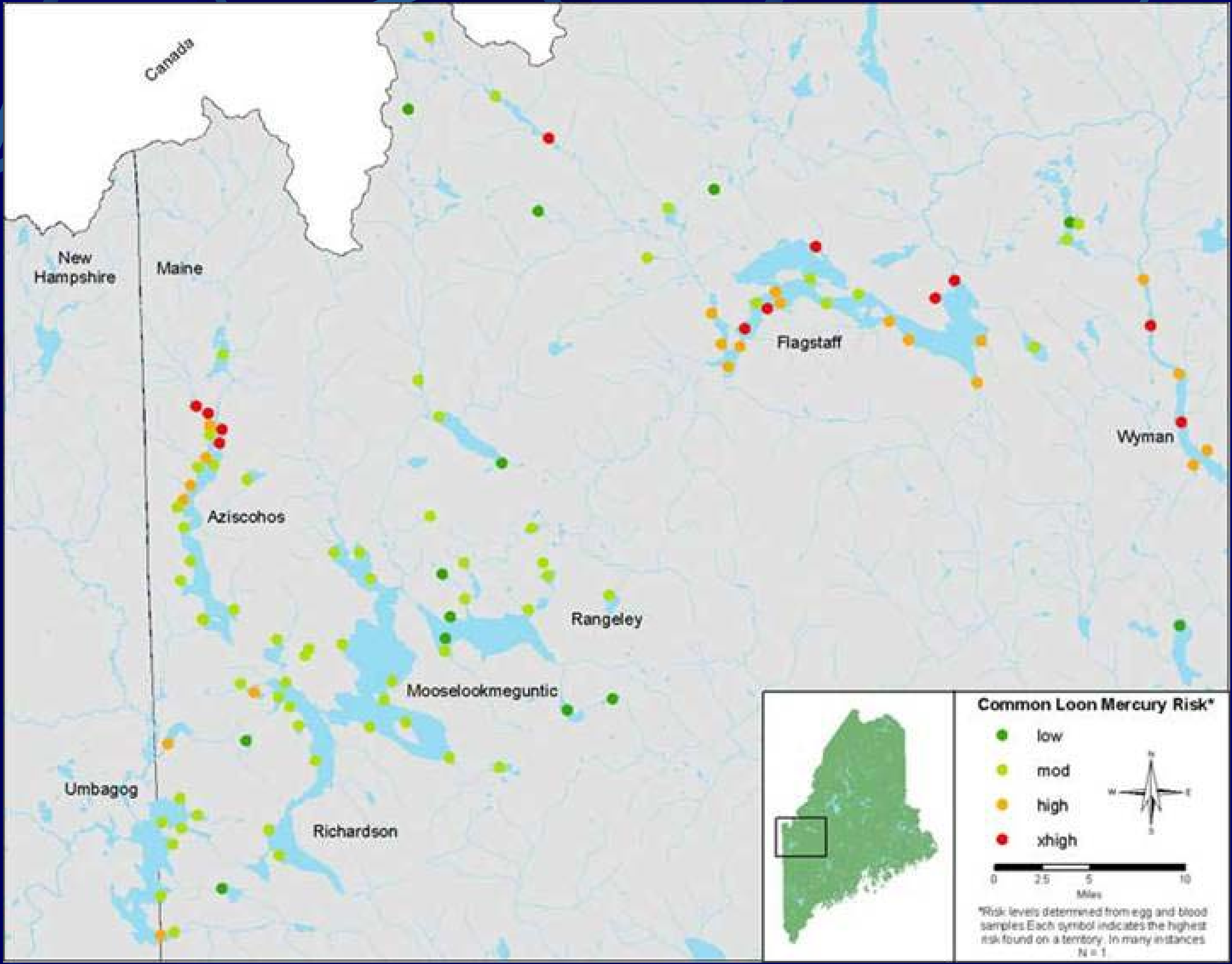
1. High trophic level obligate piscivore (biomagnification);
2. "K-selected" life history strategy (bioaccumulation);
3. Complex and coordinated behaviors within pair;
4. Moderate to high sensitivity to stressors;
5. Logistically feasible (easily observed and individually identified over entire breeding period);
6. Matrices (i.e., blood and eggs) can represent a target area
7. High profile to public and therefore policymakers;
8. Demographic models developed based on >3,000 banded loons.
9. Documented individual and, potentially, population level impacts from MeHg ingestion (based on dosing studies* and long-term field investigations);

Meyer et al. per. com.

Do current levels cause ecological impact?

Rangeley Lakes Focal Study Site

(44 lakes with 181 Loon Territories)

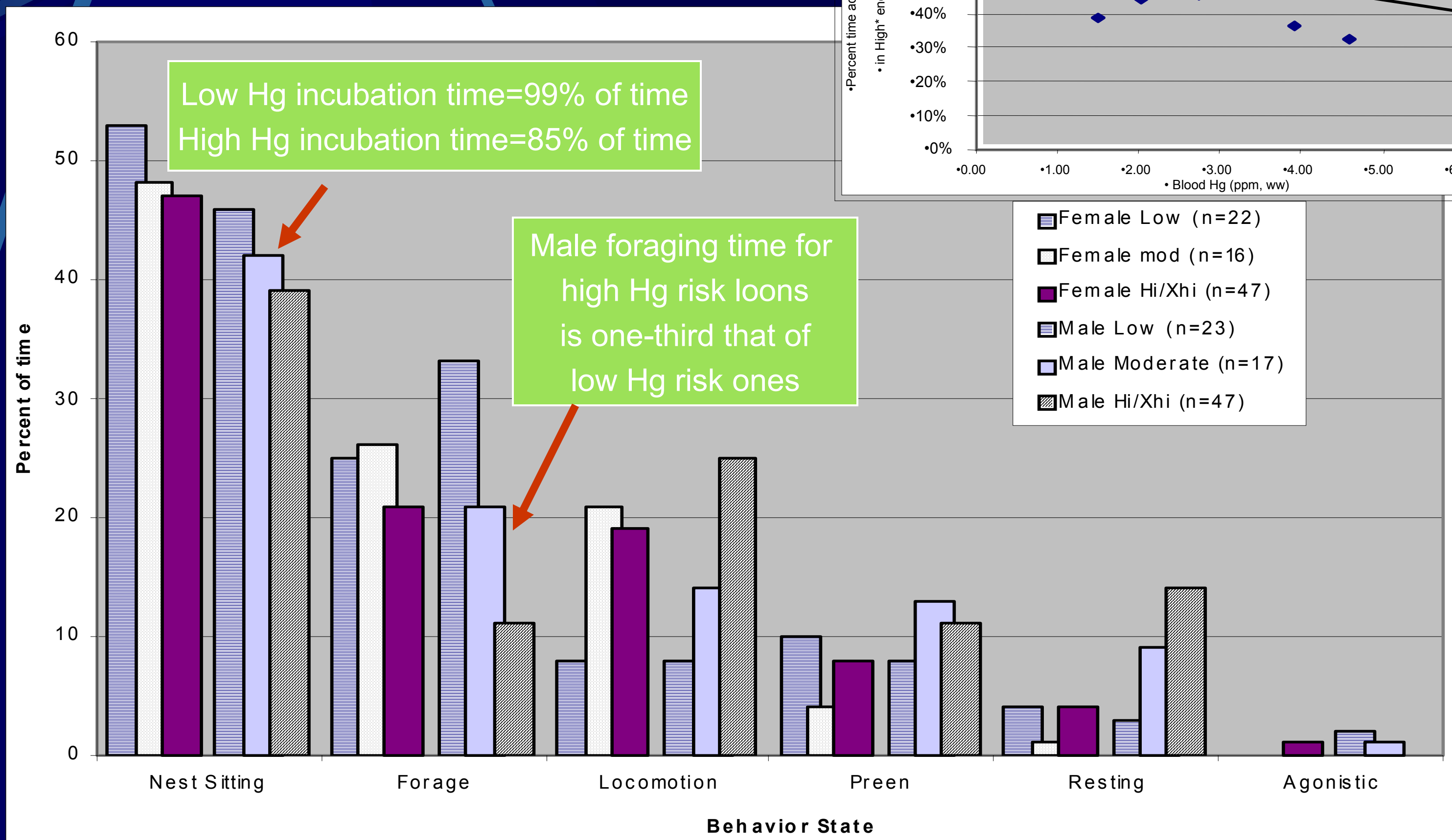


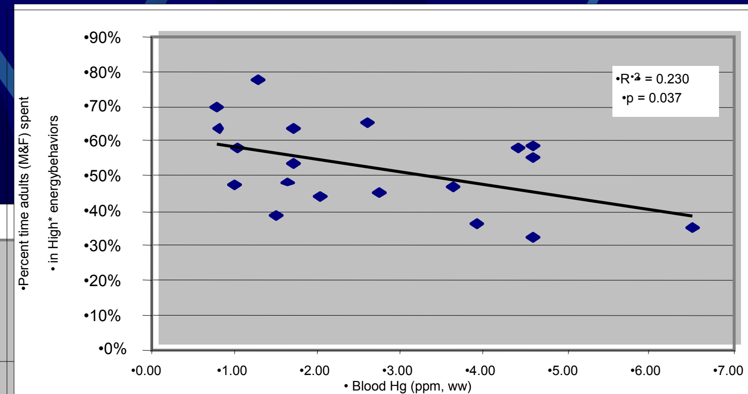
Hazard Assessment for individuals; Does Hg impact individual loons? YES

- **Physiological:**
  - Significant relationship with increasing corticosterone & MeHg
- **Behavioral** (>2,500 hours of observation)~
  - Higher Hg levels sig. reduce time incubating
  - Higher Hg levels cause adults to become lethargic (i.e., they spend sig. more time in low energy behaviors)
- **Pharmacokinetics:**
  - Recaptured adults have 9% (males) and 5.6% (females) annual increase in feather Hg levels+
  - Recaptured juveniles have increasing (1-3%/day) Hg levels during the summer

*Olson et al. Conservation Ecology
~Nocera and Diamond 1999; Conservation Ecology
+Evers et al. 1998, Environ. Tox. Chem.

Behavioral impacts



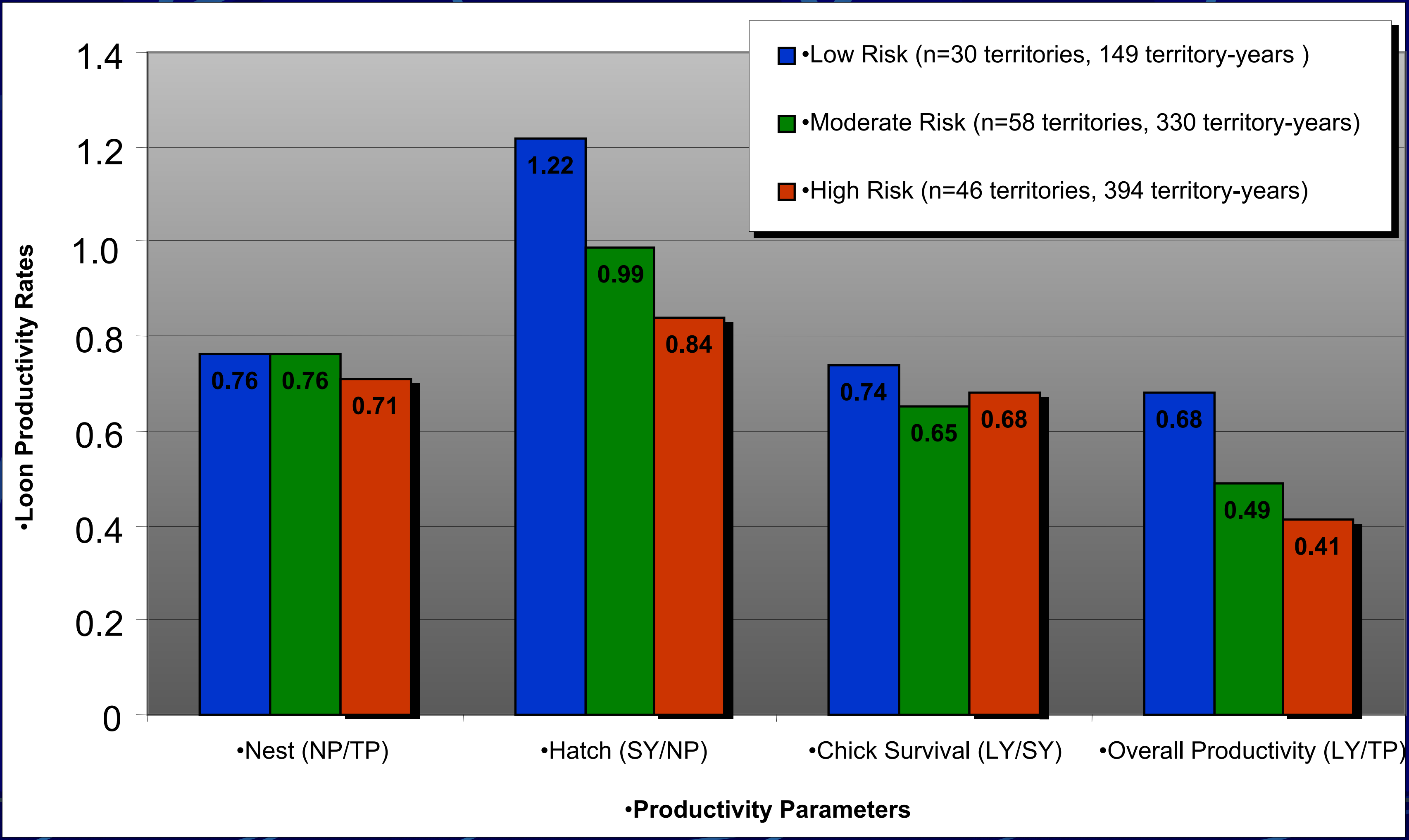


Population-level impacts from Hg; Is Hg harming loon populations? Likely

- Condition/Fitness:
  - Measurements indicate a decline related to increasing Hg.
    - Flight feather asymmetry is significant in Maine's breeding population – the 3.5% mean may result in 15% less flight efficiency
    - Recaptured high/xhigh adults show a sig. ($p=0.03$) body weight decline vs. low/mod ($n=21$).
    - Egg weights have a sig. ($p=0.02$) decline as Hg levels increase*
- Reproductive Success:~
  - Compared to low risk loon pairs, high risk pairs;
    - Significantly initiate 7% fewer nests
    - Significantly hatch 31% fewer eggs
    - Significantly fledge 40% fewer young

*Evers et al. 2003, Ecotoxicology
~Evers et al. 2004, MDEP Unpbl. Rept.

Impacts to reproductive success



Hazard Assessment - Results

		NOAEL ↓	LOAEL ↓		
Matrix	**Low**	**Mod**	**High**	**Xhigh**	**Reference**
Fish**	0-0.1	0.1-0.2	0.2-0.4	>0.4	Barr 1986, Burgess and Hobson In Press
Eggs	0-0.5	0.5-1.3	1.3-2.0	>2.0	Evers et al. 2003
Blood-J	0-0.1	0.1-0.3	0.3-0.4	>0.4	Meyer et al. 1998***
Blood-A	0-1.0	1.0-3.0	3.0-4.0	>4.0	Nocera and Diamond 1999
Feather	0-9	9-20	20-30	>30	Thompson 1998

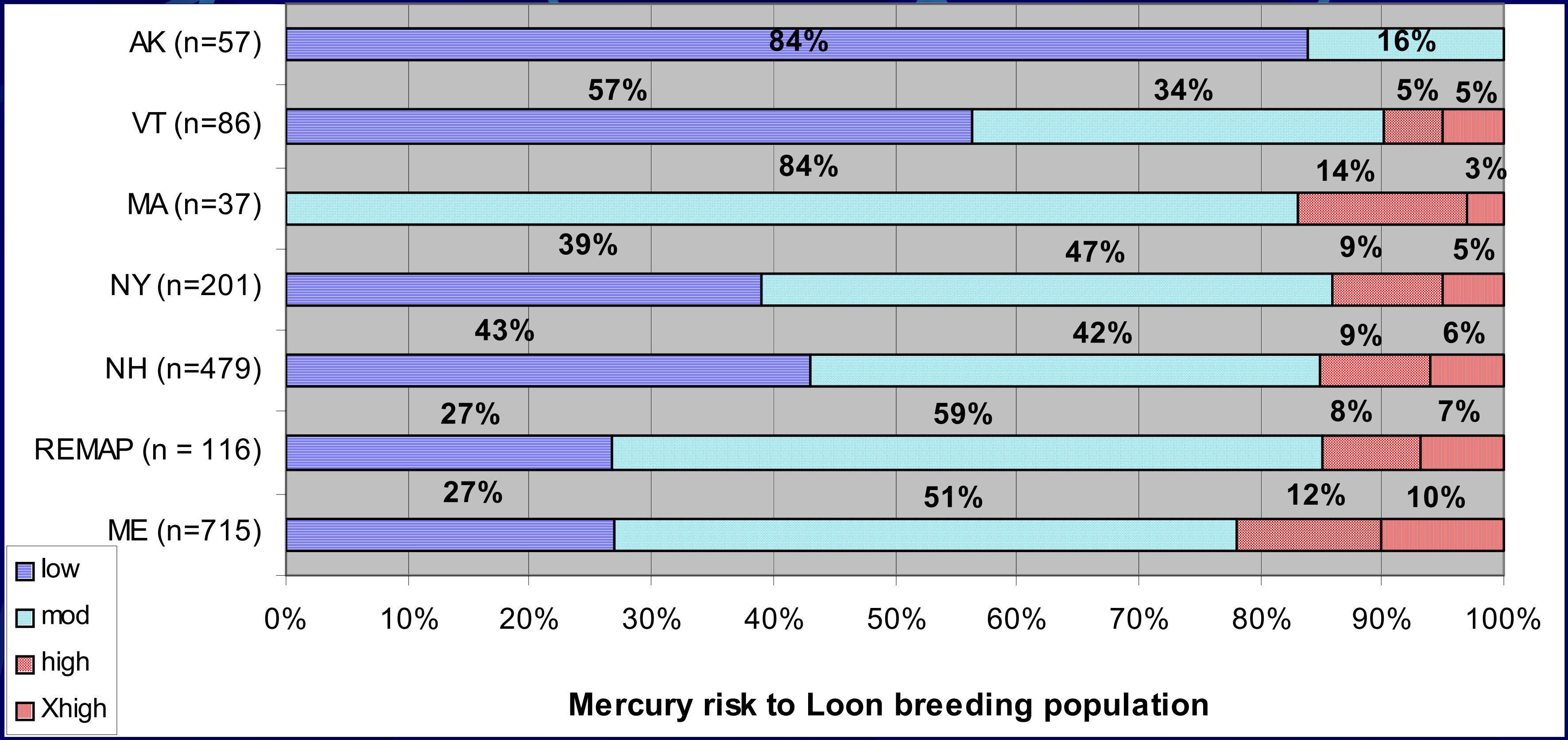
* Total Hg levels in ug/g, blood and eggs are ww and feathers are fw

** Represents 10-15 cm Yellow Perch, ww, whole body analysis

***Applies to 3-5 week old chicks only

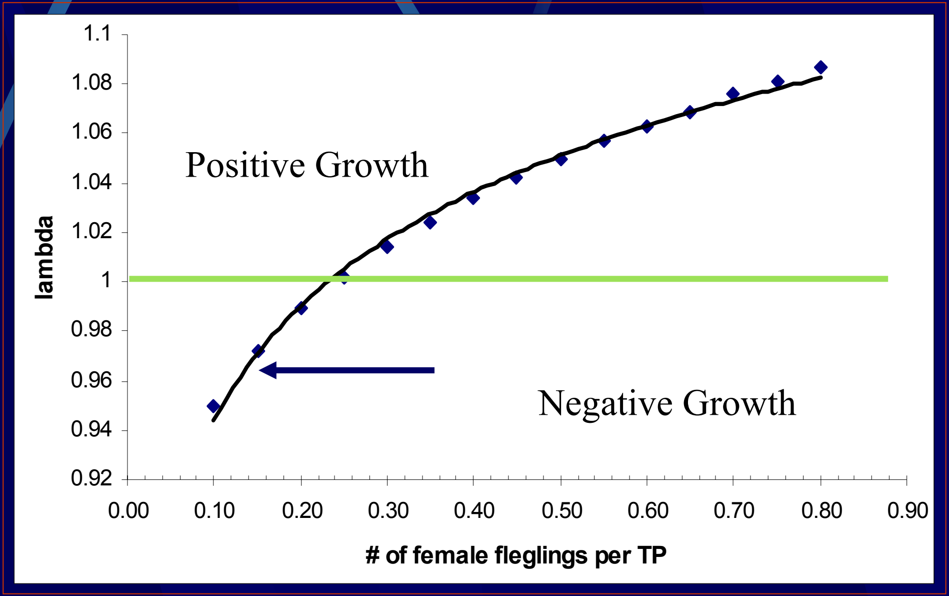
New England risk characterization

Opportunistic and Random Sampling Design



Common Loon Population Model

- Model
  - Demographic parameters mostly known
  - Needs to be spatially explicit
- Will provide a test dose for Hg that is based on:
  - Wild populations
  - Population level
- Results to date
  - Lamda = 0.48 fledged young/territorial pair
  - Validated through NH and VT long-term datasets



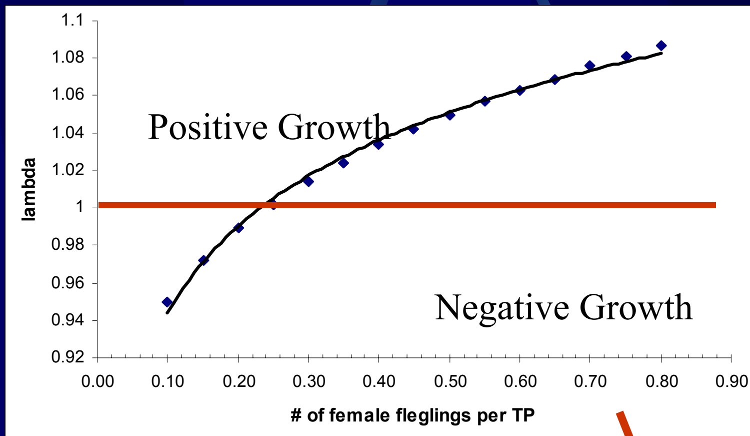
Linking science to policy

What is a WCV?

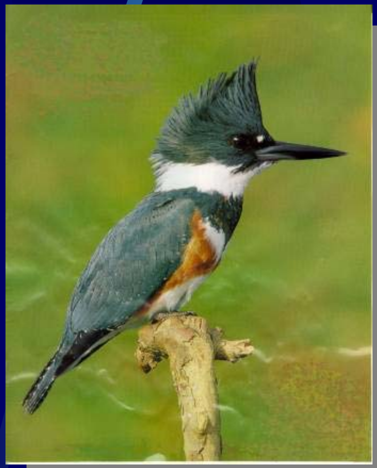
A procedure to estimate surface Hg water levels that will protect the viability of *wildlife populations* associated with aquatic resources

- First developed and used in 1995 for the Great Lakes Water Quality Initiative (GLI)
- An independently directed U.S. Congressional request in 1990 for a WCV (as mandated by the Clean Air Act) was developed by the U.S. EPA in a 1997 Report to Congress.
- Parts of this report were published by Nichols and Bradbury as “Derivations of wildlife values for mercury” in the J. Toxicology and Environ. Health, 1999.

Demographic Processes



Wildlife Criterion Value



Tested Dose from toxicity studies with wildlife species (ug Hg/kg body weight/day

UF_L=LOAEL-to-NOAEL UF
UF_A=species-to-species UF
UF_S=subchronic-to-chronic UF

Avg. species weight (kg)

$$WCV = \frac{\{TD \times [1/(UF_L \times UF_A \times UF_S)]\} \times WT_A}{W_A + [(FD_3 \times F_A \times BAF_3) + (FD_4 \times F_A \times BAF_4)]}$$

Avg. daily volume of water consumed (L/day)

$FD_{3\&4}$ =Fraction of diet from trophic level 3&4
F_A=Avg. daily mass of food consumed (kg/day)

$BAF_{3\&4}$ = aquatic life bioaccumulation factor for trophic level 3 & 4 (L/kg of MeHg in fish / MeHg in water)

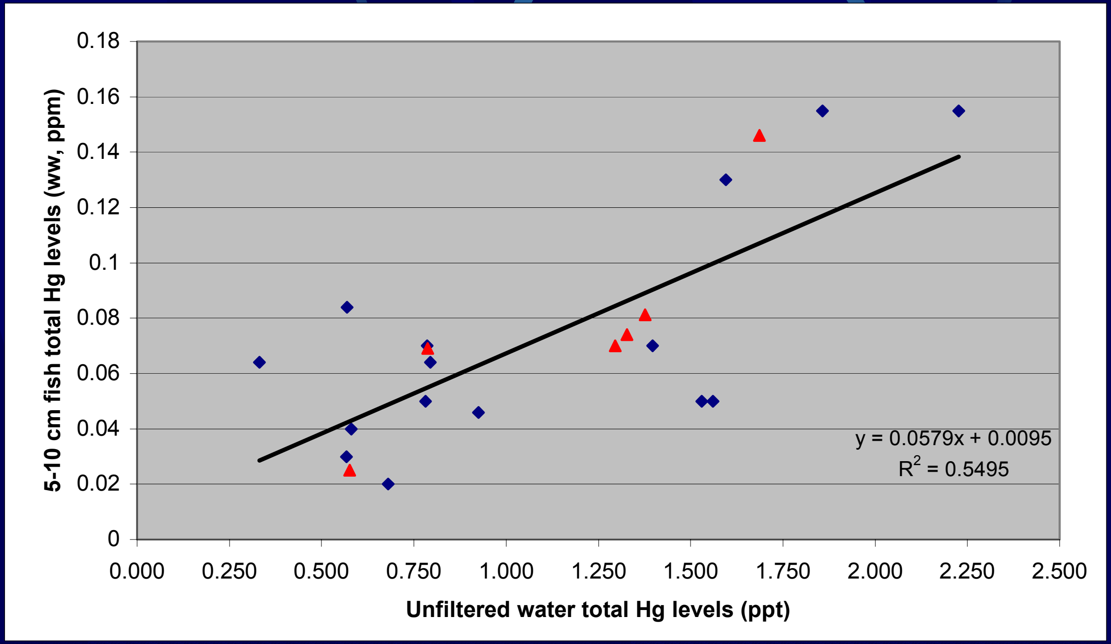
Test Dose

- EPA WCV limitations
  - Test dose is:
    - Based on mallards, non-piscivorous birds that are more sensitive to Hg toxicity because for evolutionary reasons;
    - Based on laboratory studies;
    - Based on impacts to individuals.
  - Ingestion rates and BAF are quite generic and are not based on empirical data.

- BRI WCV (response to limitations in EPA model)
  - Test dose is:
    - based on a species that is sensitive to Hg toxicity and is exposed to Hg levels that are significantly higher than historical levels on freshwater lakes;
    - Based on in-field studies:
    - Based on impacts to populations.
  - Ingestion rates and BAF are empirically measured parameters.

Bioconcentration Factor

1. Total Hg in unfiltered water related to yellow perch Hg (whole body, ww)
   - BAF for Trophic Level 3 fish (5-15 cm) = 86,250
   - BAF for Trophic Level 4 fish (15-25 cm) = 156,330
2. Total Hg in unfiltered water related to perch or perch equivalents
   - Best relationship with 5-10 cm size class (explains 55% of variation)
   - Species-to-species conversion is 1.15 for centrarchids, golden shiner, trout
3. Water-fish MeHg relationship is being investigated in New York



WCV for Hg based on population levels of the Common Loon

$$WCV_{\text{Male Loon}} = \frac{0.179 \text{ mg/kg/d x [1/3 x 1 x 2)]) x 5.95 kg}}{0.012 \text{ L/d + [(0.73) (1.19 kg/d x 86,250) + (0.27) (1.19 kg/d x 156,330)}}$$

$$\mathbf{WCV_{\text{Male Loon}} = 1.418 \text{ ng/L}}$$

$$WCV_{\text{Female Loon}} = \frac{0.142 \text{ mg/kg/d x [1/3 x 1 x 2)]) x 4.71 kg}}{0.012 \text{ L/d + [(0.83) (0.943 kg/d x 86,250) + (0.17) (0.943 kg/d x 156,330)}}$$

$$\mathbf{WCV_{\text{Female Loon}} = 1.204 \text{ ng/L}}$$

Where do emission point sources have the greatest impact?

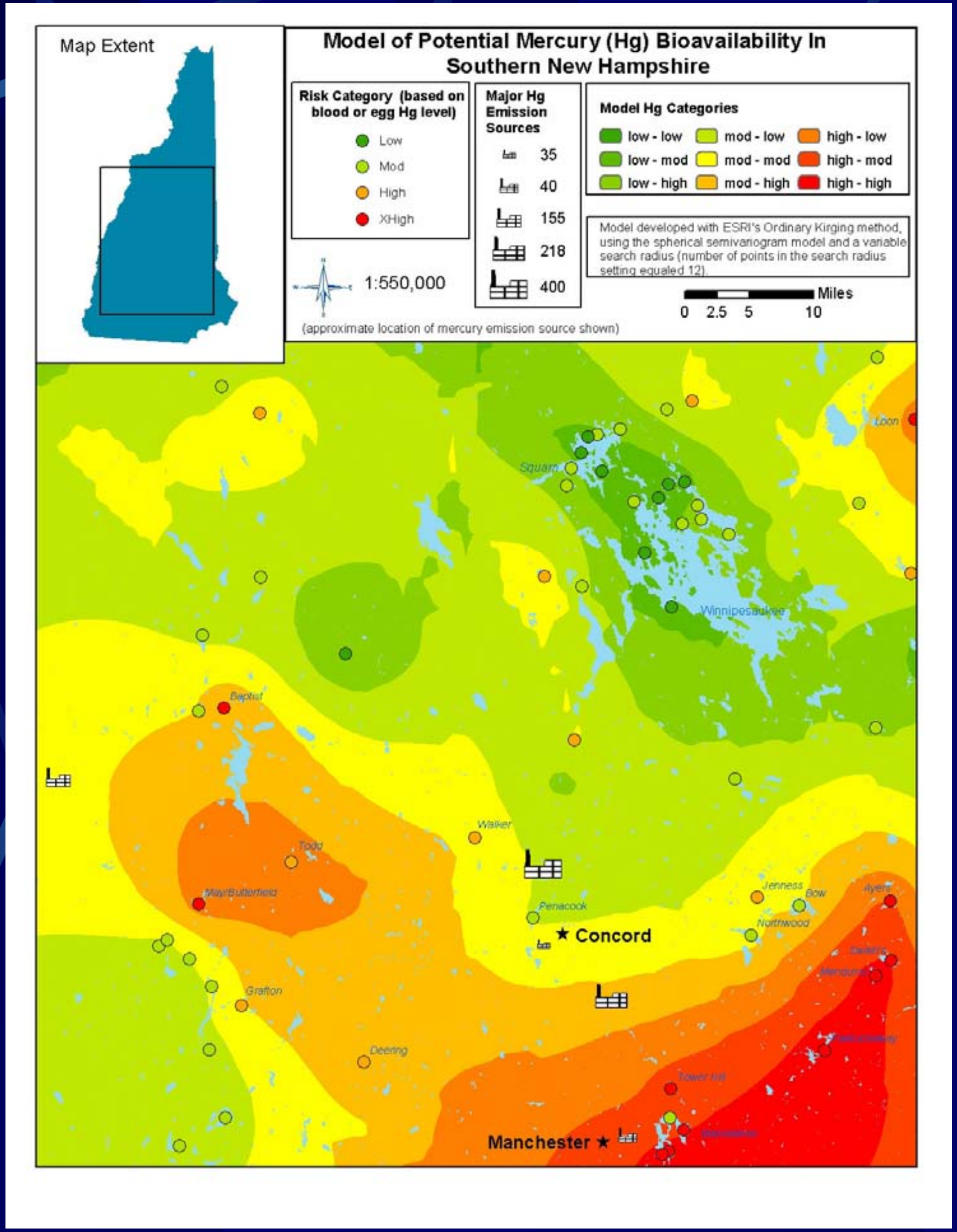
Southeastern New Hampshire "hotspot"

1. Detected by USEPA atmospheric deposition models

2. Likely related to high Hg emissions from local municipal and hospital waste incinerators and coal-burning power plants

3. Loon tissue Hg results (n=266 samples; 47 lakes)

4. Recent assessments show a decline in the biotic Hg signal



Much is known….what's next?

- Determine Hg effect levels on wildlife (LOAELs)
  - Loon emphasis in Northeast (*in situ*) and Wisconsin (lab/*in situ*)
  - Insectivorous bird emphasis in Northeast (*in situ*) and Patuxent Wildlife Research Center (lab)
- Further understand Hg relationships in systems (i.e., reservoirs) that do not follow NSRC models (long-term USDA NSRC grant)
  - Relate abiotic and biotic Hg levels with exposed shoreline
  - Further explore biodilution, where plankton structure dictates biomagnification
  - Investigate the interaction among reservoirs with varying hydrology and chlorophyll A levels

- Develop spatially-explicit wildlife criterion value (WCV) for Hg
    - In process for Maine (fourth year) and New York (second year)
    - Vermont and New Hampshire??
- Summarize Hg databases into a common database, model Hg relationships, and publish results
    - In process through the USDA's Northeastern Ecosystem Research Cooperative (NSRC): Special double issue in Ecotoxicology published in early 2005

Collaborators

FEDERAL GOVERNMENT

- U.S. Fish and Wildlife Service – New England Field Office and Office of Migratory Bird Mgmt.
- U.S. EPA – ORD Narragansett Office – Atlantic Ecological Div. & the New England Field Office
- U.S.D.A. – Northeastern Ecosystem Research Cooperative
- Canadian Wildlife Service

STATE GOVERNMENT

- Maine Dept. of Environ. Protection & Inland Fish and Wildlife
- Mass. Dept. Conserv. & Resour.
- NH Dept. of Environ. Service
- NY State Dept. of Environ. Cons.
- Vermont Dept. of Environ. Cons.

NON-PROFIT / UNIVERSITY

- Adirondack Coop. Loon Program
- Buffalo State College
- Loon Preservation Committee
- Maine Audubon Society
- Texas A&M Trace Element Res. Lab
- Tufts University
- Univ. of Pennsylvania
- Univ. of Southern Maine
- Vermont Inst. Of Natural Science
- Wildlife Conservation Society

INDUSTRY

- FPL Energy Maine Hydro
- New York State Energy Research and Development Authority