Assessment of Hg in Sediment, Water, and Biota of VT and NH Lakes

A Collaborative REMAP Project

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VT / NH REMAP-Hg Project Collaborators

- NHDES
- VTDEC
- Syracuse University
- Dartmouth College
- Sci. Museum of Minnesota
- US Fish and Wildlife Service
- VT Dep’t of Fish and Wildlife
- BioDiversity Research Institute

Project inception

- In 1997, we knew very little about Hg levels in lakes of northern New England, outside of Maine.
- Application of sampling and analytical methods for trace metal work were just becoming available outside of academic realm.
- EPA Region 1 developed a strong interest in having a complete picture of Hg contamination across the entire region.

Core program goals for the period 1998 to 2000

- Use USEPA “EMAP” approach to:
- Identify the physico-chemical identity(ies) and hypothesized trophic Hg transfer pathway of lakes which pose a risk of Hg contamination to people and wildlife;
- Model Hg signal in lakes outside the study set, which can identify target waters for further fish/avian assessments;
- Model air deposition using MDN / UMAQL network
- Understand the historical accretion patterns of Hg into lakes as a tool to understand potential gains given reduced Hg deposition.

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Study design:

- 90+ lake geographically randomized sample
- Hg and meHg collections in water, sediment, plankton, fish, avian piscivores, sediment cores
- Hg-clean methods used for all Hg collections
  - Water by CVAFS
  - Mud and Biota by CVAA
- Dataset describing current Hg conditions,
- Design permits geographic analyses, and
- Dataset ripe for opportunistic analyses (e.g. mining).

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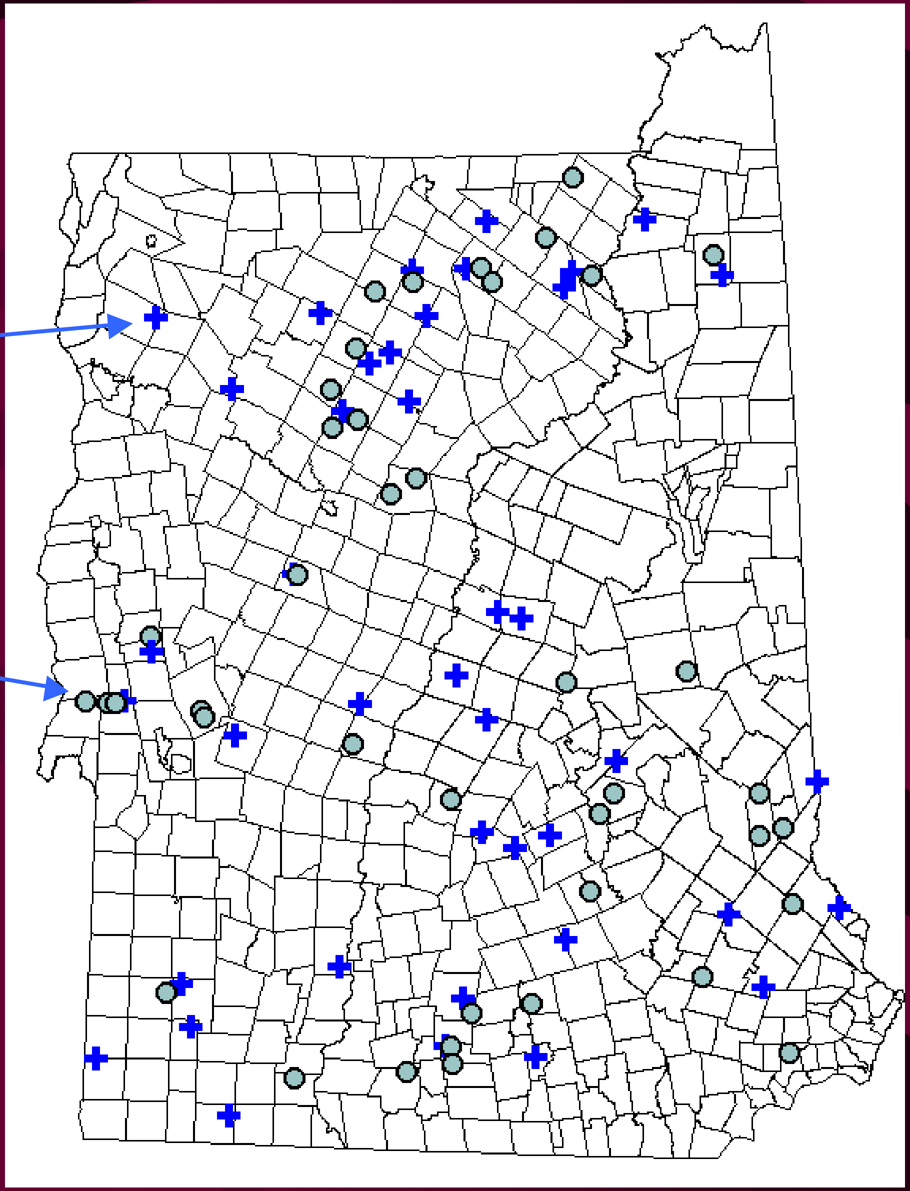
Parameter list

- Water: Hg, meHg, nutrients, DOC and acid-base chemistry, physicochemical measures
- Sediment: Hg, meHg , solids and organic content
- Macrozooplankton – Hg, bulk >200*u* fraction
- Yellow Perch in two size classes, Hg and meHg
- Upper trophic level piscivore tissue Hg (e.g., loons, kingfisher): blood, feather, egg

Study lake locations

1998

1999



VT / NH REMAP-Hg Project
In the field

VT / NH REMAP-Hg Project
In the field

Considerations for clean water collections

VT / NH REMAP-Hg Project
In the field

Clean, undisturbed overlying water

Perfect sediment-H2O interface

Core laminae

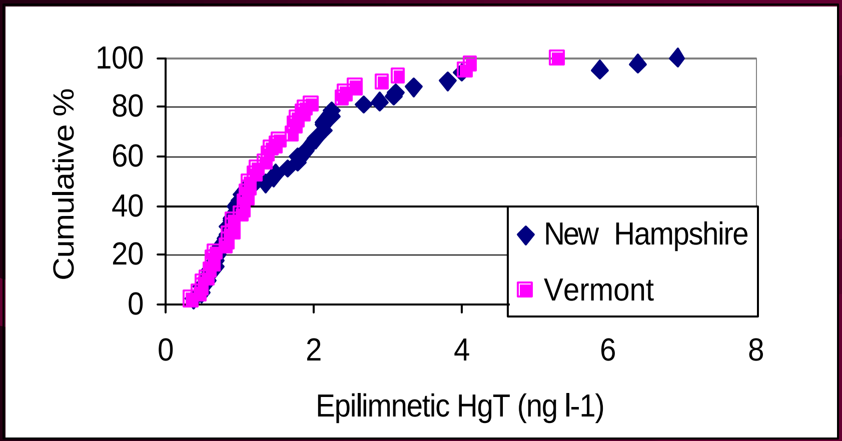
VT / NH REMAP-Hg Project
In the field

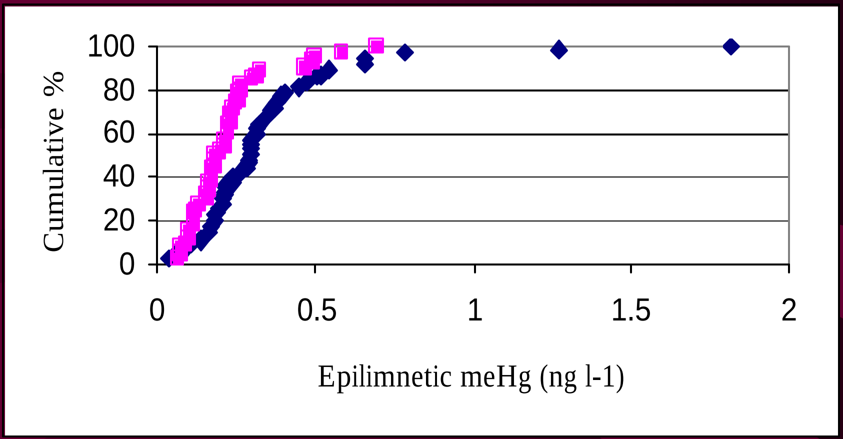
VT / NH REMAP-Hg Project

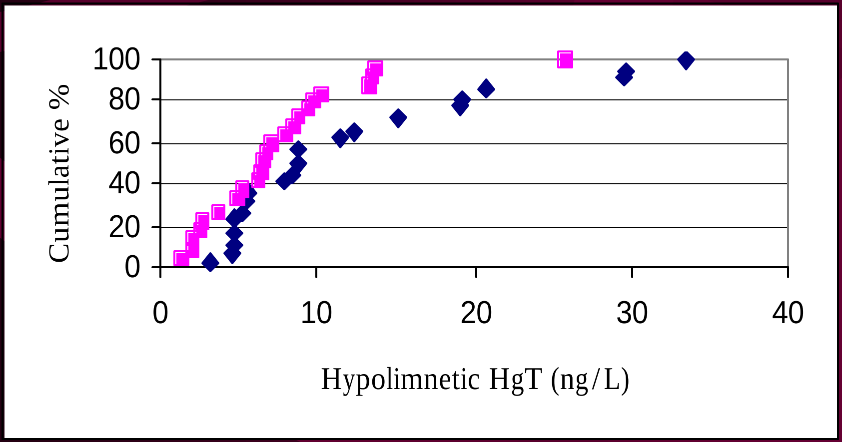
Findings:

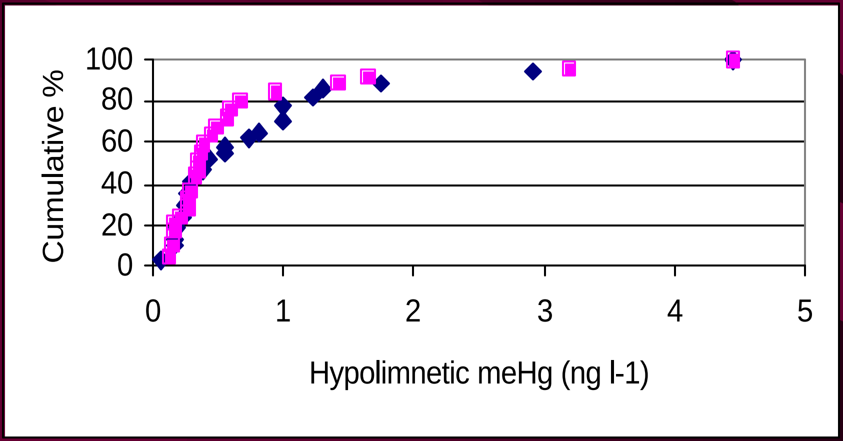
- Cumulative frequency distributions
- Hg and lake trophic status
- Hg and land-use
- Water chemistry and methylation
- Predicting tissue Hg
- Piscivore Hg risk assessment
- Air deposition models
- Historic and current Hg accumulations

VT / NH REMAP-Hg Project Findings: Water Hg









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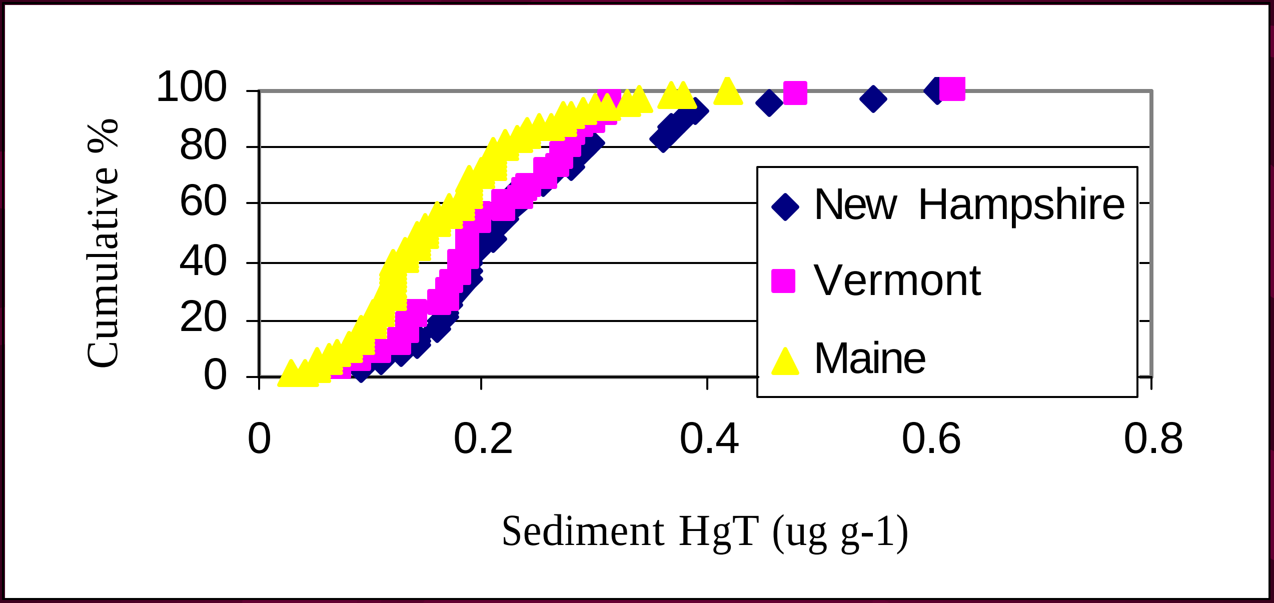
Findings: Sediment Hg



Sediment methylHg ranges from <0.0006 ug g^{-1} to 0.021 ng g^{-1}

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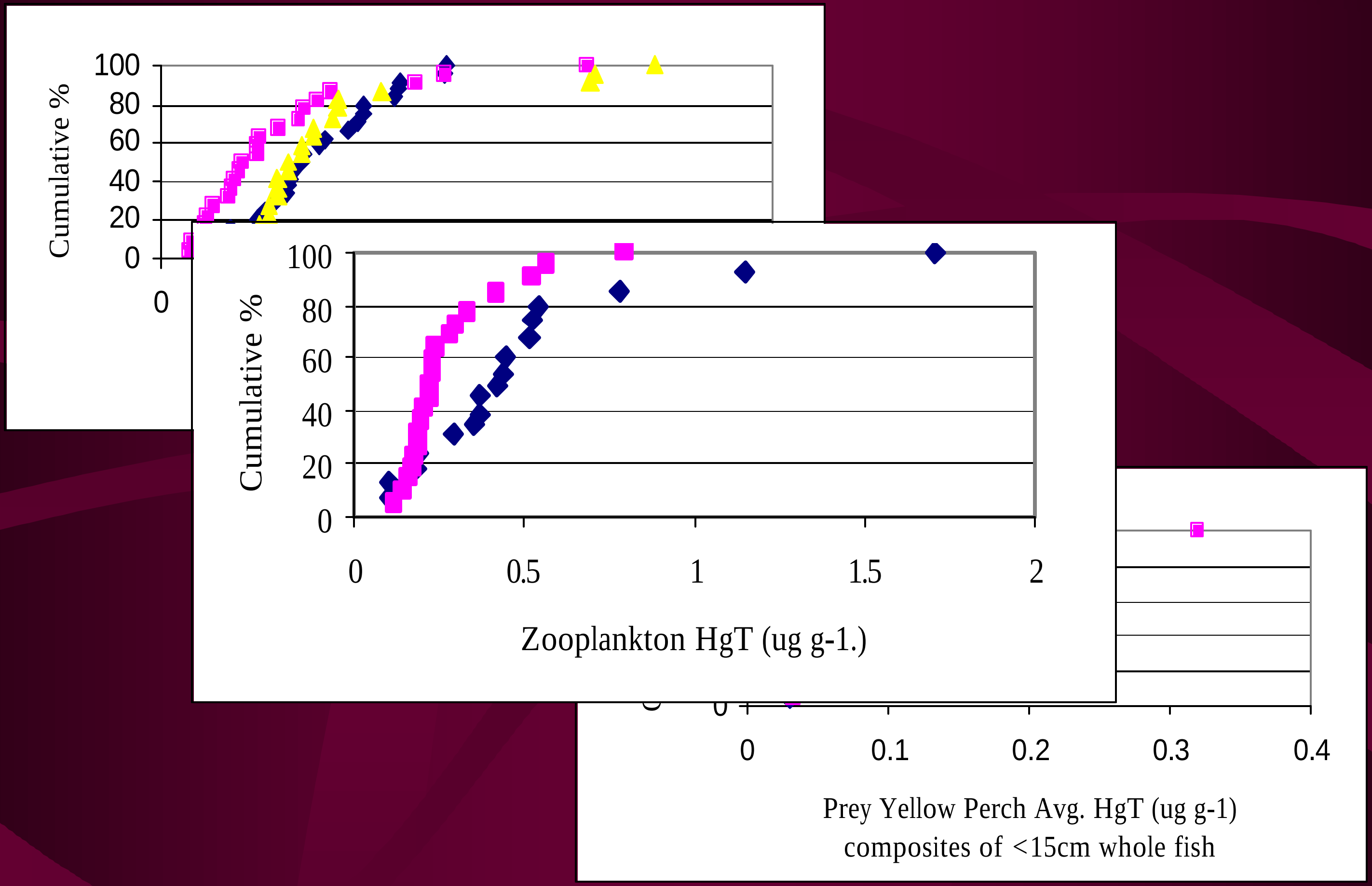
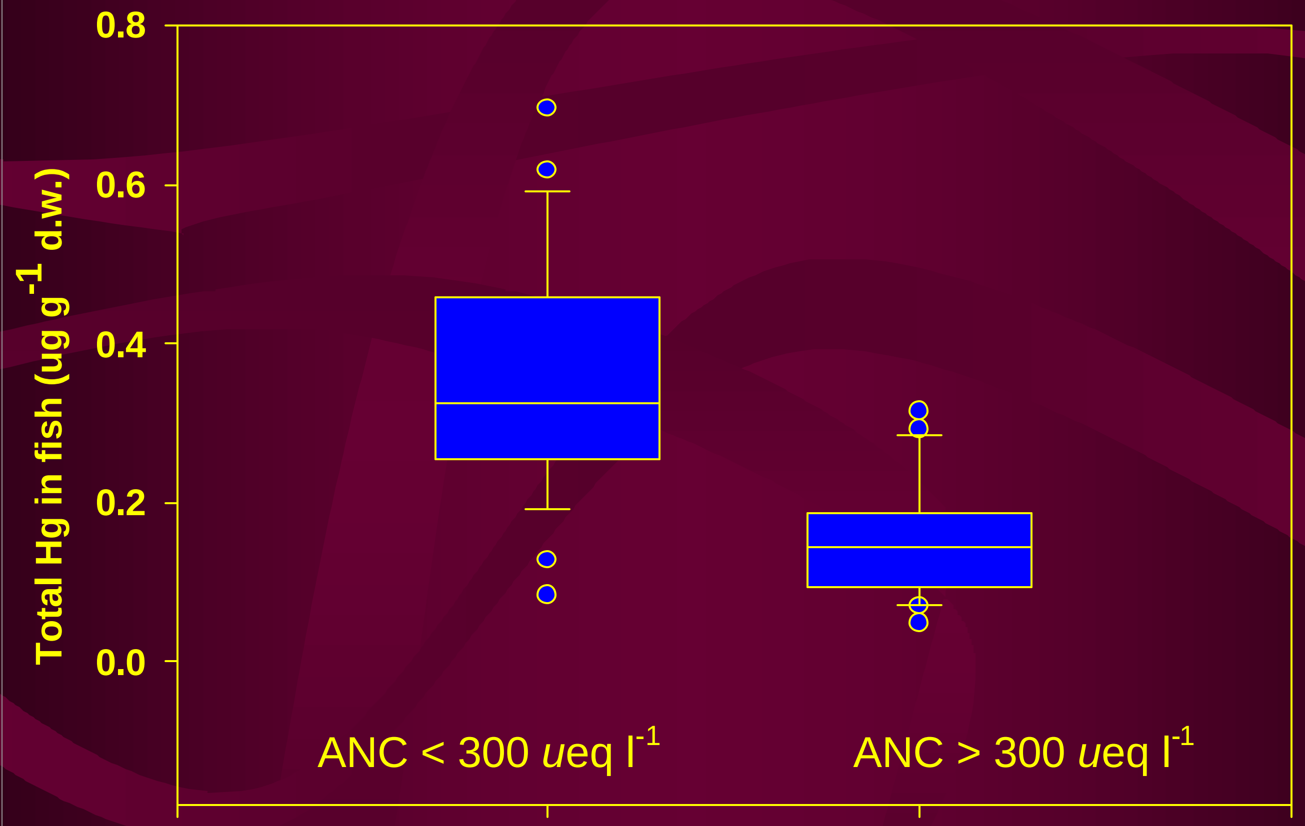
Findings: Tissue Hg



VT / NH REMAP-Hg Project Findings

Hg in Yellow Perch

Fish in acidic lakes have elevated Hg in their tissue:



VT / NH REMAP-Hg Project
Hg and Lake Trophic Status

- Bloom Dilution
  - Pickhardt et al. PNAS 2002.
- More algae means less Hg per unit algae
- So lakes of elevated trophic status should show less Hg in the plankton, and therefore less bioaccumulation.

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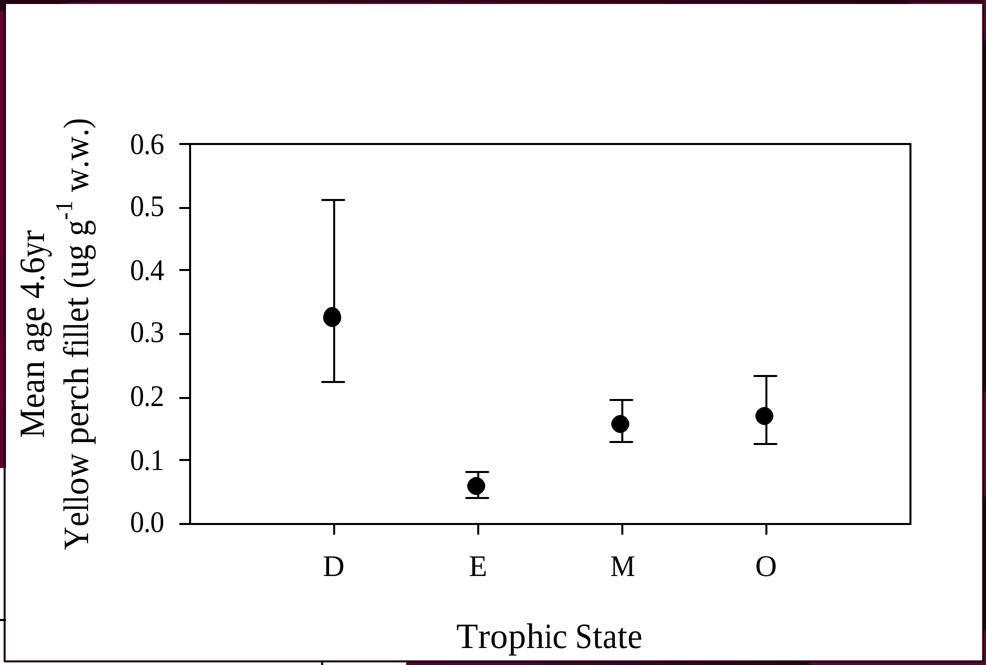
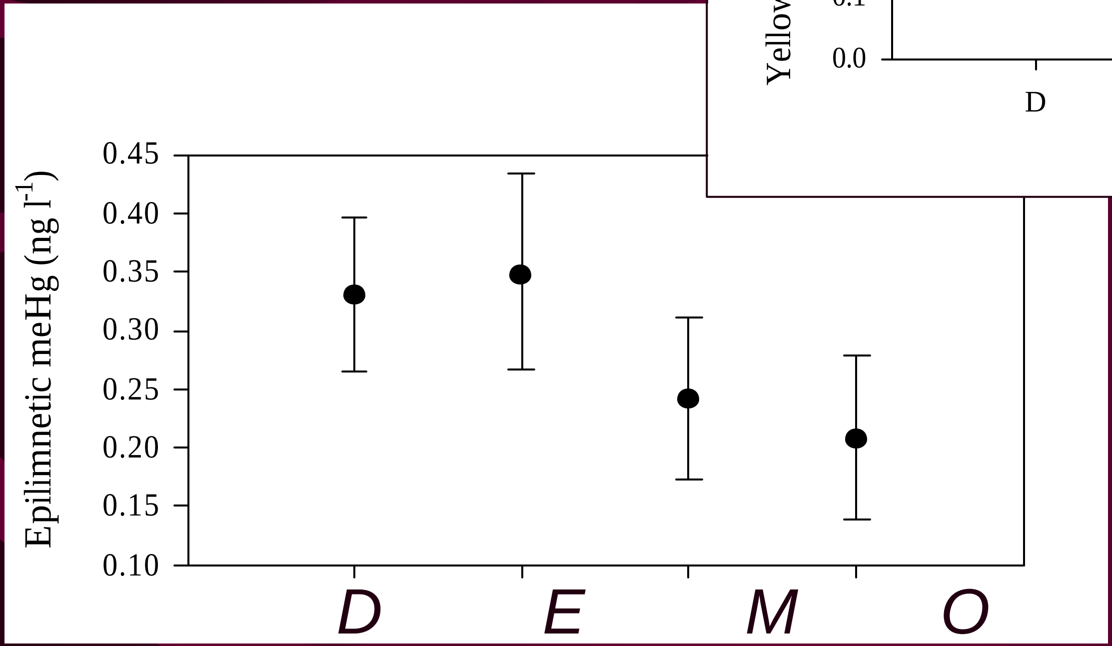
Lake trophic status





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Hg and Land Use

- Do forested and wetland rich watersheds deliver more Hg? Literature says they should.
- What about developed watersheds?

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Land use correlations (Spearman)

	% Forested	% Ag.	% Wetland & water	% Dev.	E911
HgT	ns	ns	ns	ns	**-0.32**
meHg	**0.228**	ns	ns	ns	**-0.198**
Sed. HgT	ns	**-0.33**	ns	ns	**-0.53**
Perch fillet HgT	**0.38**	**-0.216**	ns	**-0.41**	**-0.239**

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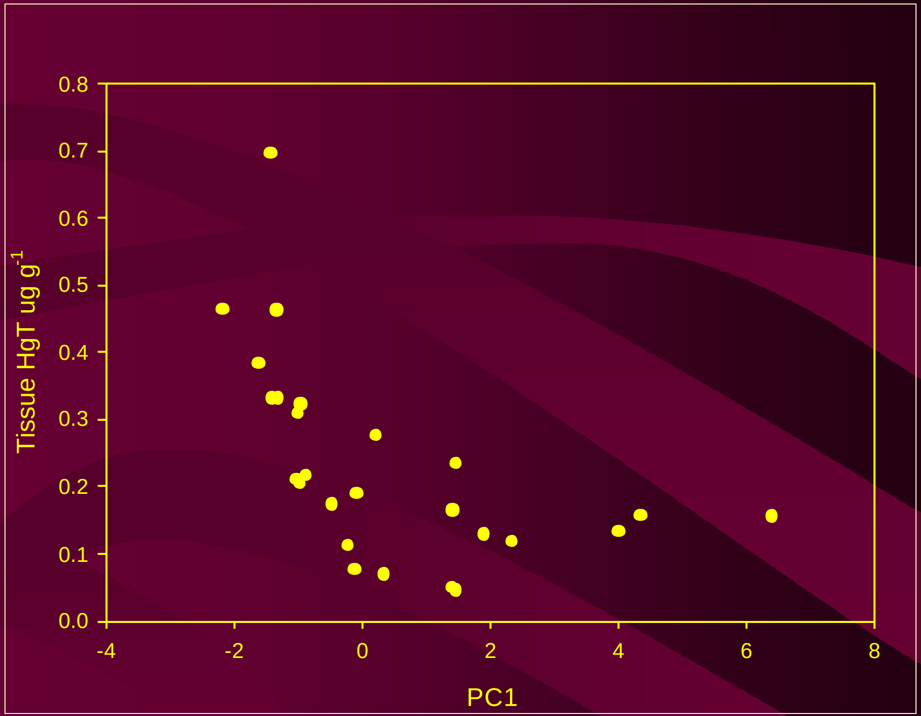
Water chemistry influences

There is too much heterogeneity of lake types and factors to yield satisfactory ‘univariate’ relationships.

Joint ‘multivariate’ distributions provide insight into how the interaction of factors controls Hg.



PC1→: +Cond, +ANC, +pH, +SO4, +CL-

Modeling compliance with tissue criterion

Yellow perch fillets <0.3 ug g^{-1} HgT, Meets EPA Criterion:

-1,580 – 82.92(lnANC) + 45.35(lnDOC) + 1,658(ln_pH) - 18.99(lnCond) – 35.09(invrtFlush) Eq. 1.

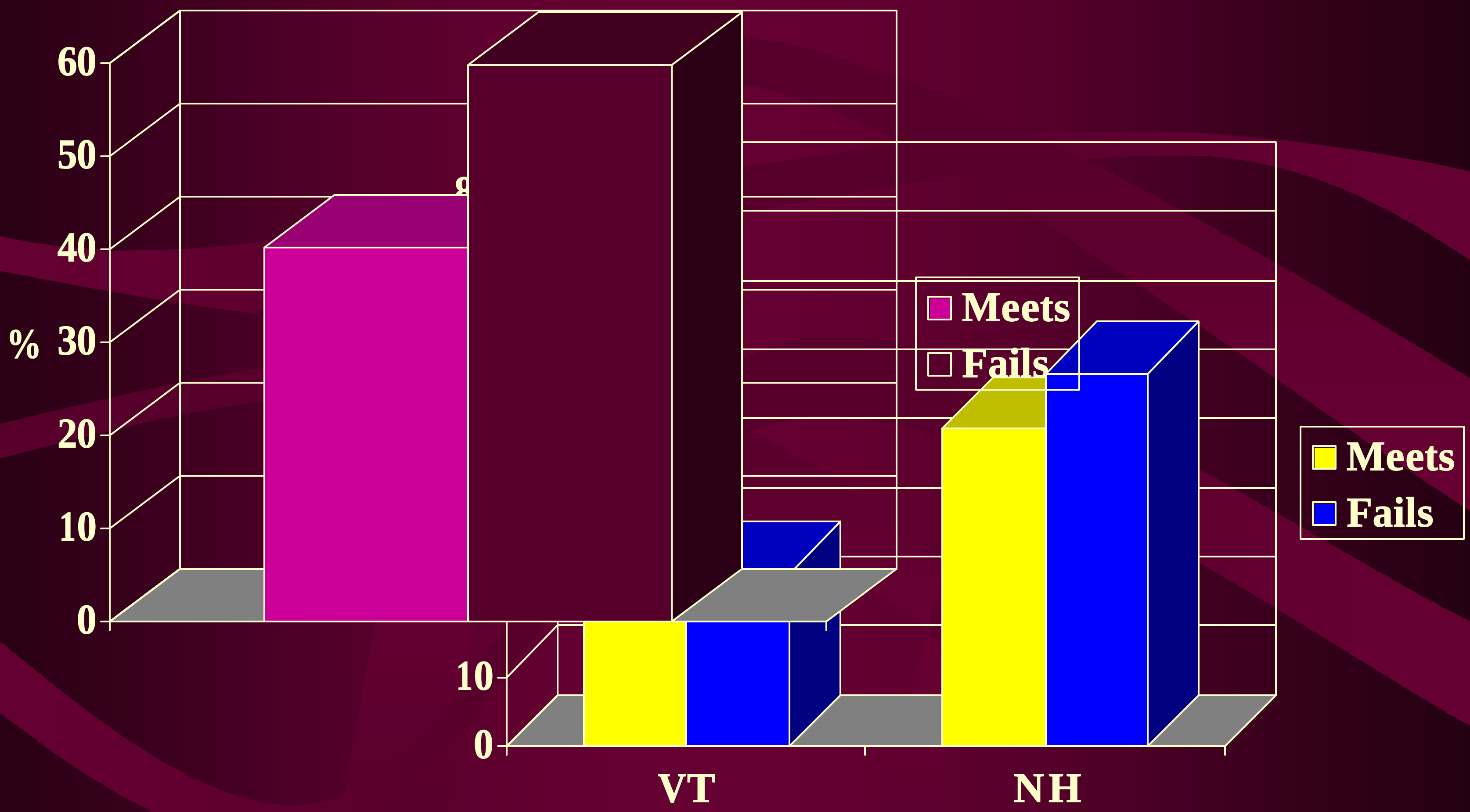
Yellow perch fillets >0.3 ug g^{-1} HgT, Violates EPA Criterion:

-1,494 – 81.94(lnANC) + 48.49(lnDOC) + 1,610(ln_pH) – 18.65(lnCond) – 33.02(invrtFlush) Eq. 2.

Where:

lnANC = ln (1+acid neutralizing capacity, in mg l^{-1}, measured from the epilimnion)
lnDOC = ln (1+dissolved organic carbon, in mg l^{-1}, measured from the epilimnion)
ln_pH = ln (1+pH, in standard units, average of total water column)
lnCond = ln (1+conductivity, in us cm^3, average of total water column)
invrtFlush = (Flushing rate, in # $yr^{-1})^{-2}$

Modeling compliance with tissue criterion



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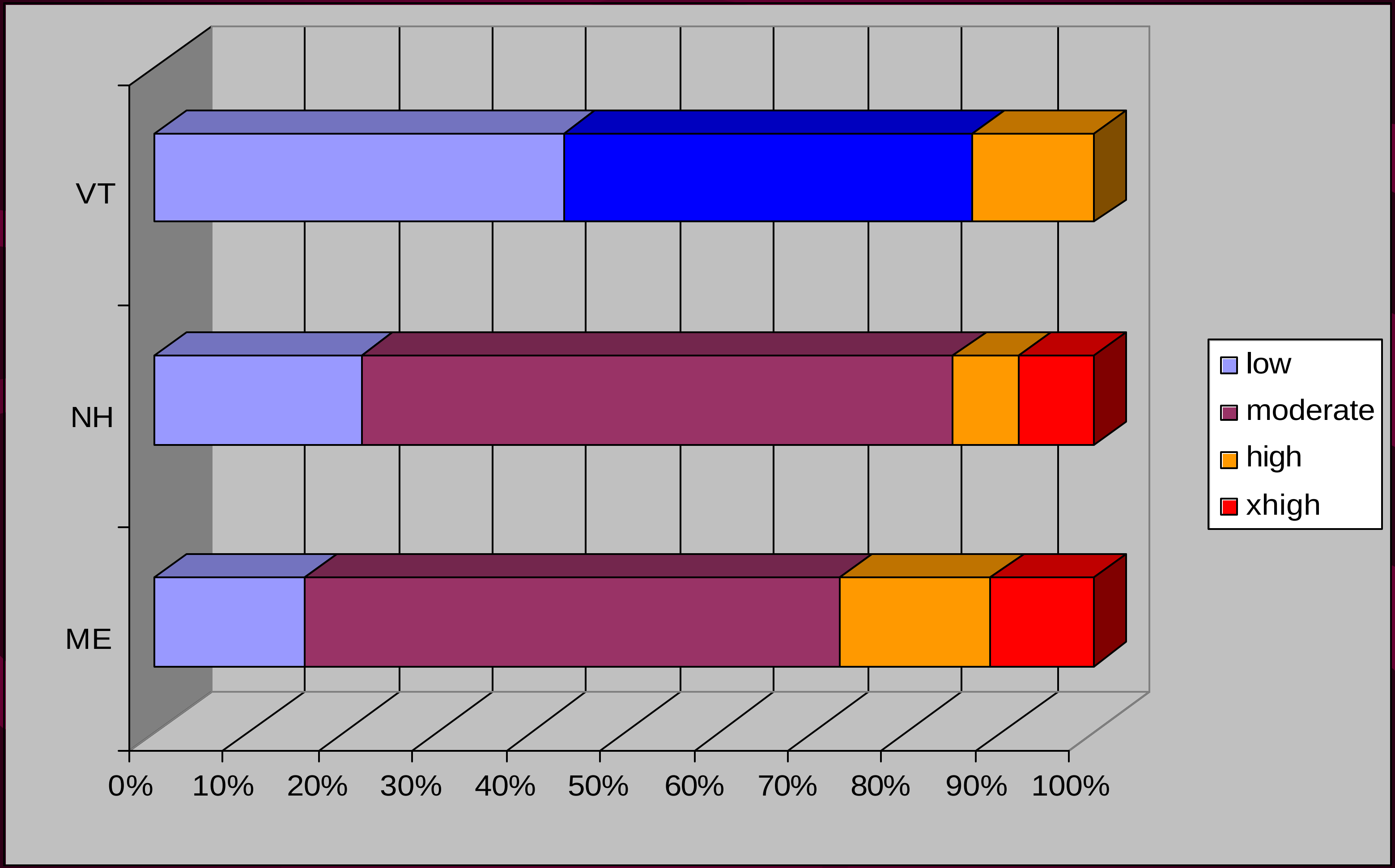
Cumulative Risk Index based on Hg in Loon Blood



History of Hg Accumulation:

Atmospheric Hg Deposition

- Can wet Hg deposition be modeled given existing MDN / UMAQL network?
- What about dry Hg deposition?

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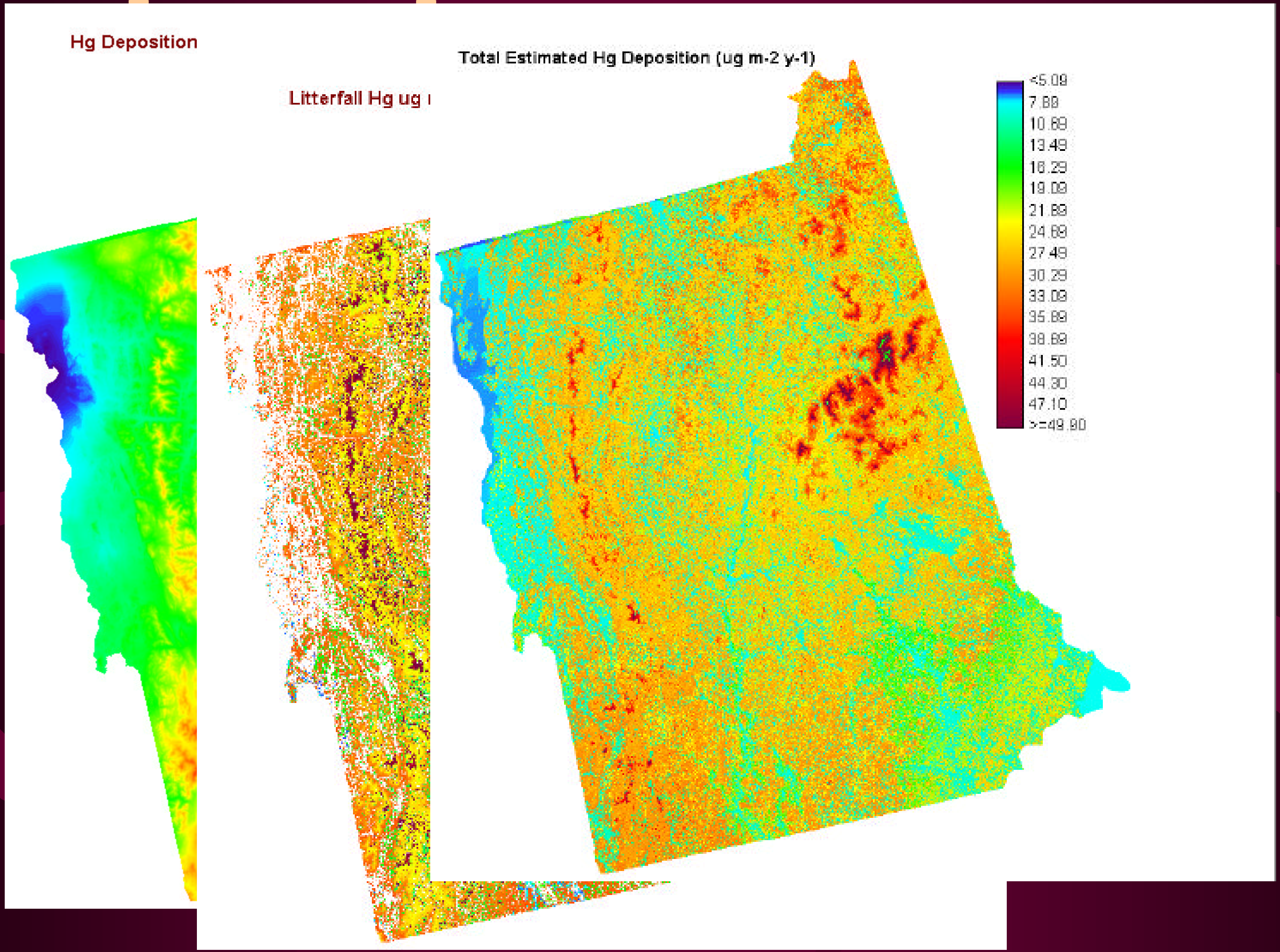
Atmospheric deposition

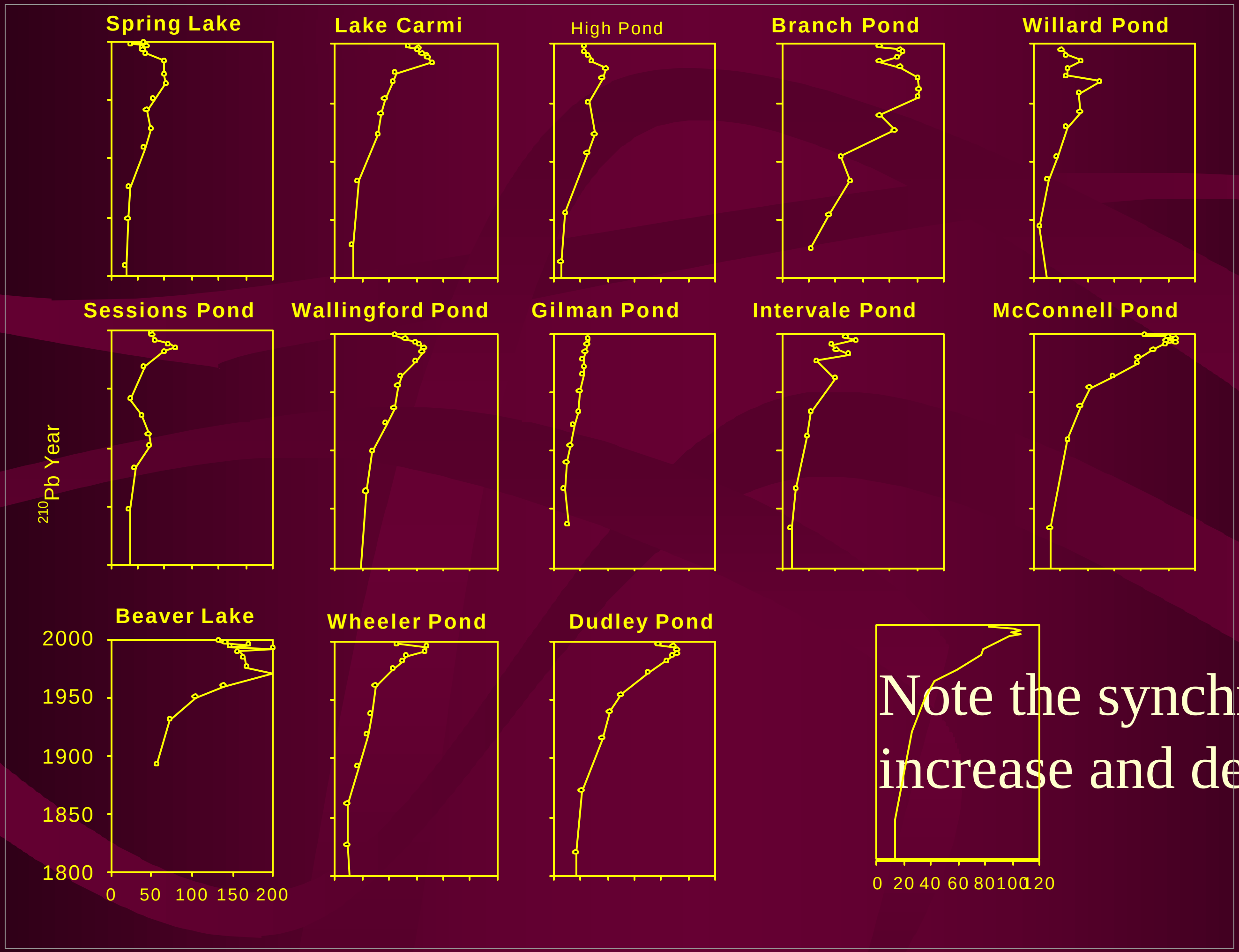


VT / NH REMAP-Hg Project

- Is the Hg flux rate to VT and NH lake sediments presently increasing or decreasing?
- Can we then infer changes in the atmospheric deposition rate?

VT / NH REMAP-Hg Project Findings

HgT Fluxes ($ug \cdot m^{-2} \cdot yr^{-1}$)



Note the synchrony of flux increase and decrease

Increasing Basin Area / Lake Area

VT / NH REMAP-Hg Project Synopsis:

- Hg concentrations in VT and NH lakes range widely. [ ]'s are greater in NH, and in lake hypolimnia.
- Yellow perch fillets vary w/ age and size, and age-correction most accurately captures variation in Hg accumulation rates across lakes.
- Hg, meHg, and tissue Hg all vary with trophic status. Eutrophic and dystrophic lakes have higher meHg, but only dystrophic lakes show higher tissue Hg.

VT / NH REMAP-Hg Project Synopsis:

- MethylHg varies significantly w/ numerous water chemistry parameters. The way these parameters inter-relate is important to understanding in which lakes meHg is more readily produced.

- For VT-NH lakes, the likelihood that yellow perch tissues will violate current criteria can reasonably be modeled using simple parameters.

VT / NH REMAP-Hg Project Pubs:

- Paleolimnology
  - *Atmos. Environ.* 2003.
- Water and Tissue Chemistry and Statistics:
  - *Env. Tox. Chem.* 2004.
- Modeling, air deposition:
  - *Ecotoxicology in prep*.
- Modeling: Air+watersheds+in-lake interactions
  - Ongoing w/ EPA-ORD

How does this all get used??

- TMDL's
  - Air dep maps and by-lake estimates provide one estimate of critical loads – these dep maps are in preparation for all of NE presently
  - Additional modeling can and will follow w/ these data
- Env. Indicators:
  - CDF's provide reproducible, statistically valid estimates of region-wide contamination signals
  - Paleo profiles provide reproducible, statistically quantified and landscape-integrated estimates of deposition, both presently and historically
- NERC Hg project for NE US and SE Canada.
- EPA Regional Modeling Project