MERGANSER: A Model for Predicting Mercury Levels in Wildlife in New England

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- Others on MERGANSER Project team

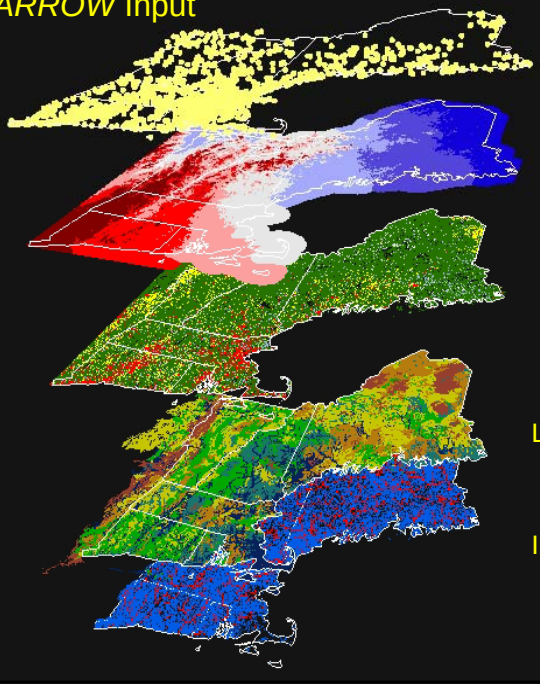
Outline

- Genesis of idea for MERGANER: New England SPARROW
- Conceptual model
- Alternative model forms/estimated equation
- Predictor & Response Variables
- Issues & Current focus
- Endpoints: Linking MERGANSER with policy

Genesis of idea for MERGANER: New England SPARROW

- "Spatially Referenced Regressions on Watershed Attributes" - uses regression equations to relate total N & P (nutrient) stream loads to nutrient sources and watershed characteristics (USGS, Smith et al, 1993 & 1997; Moore et al, 2004)
- Produces estimates, with uncertainty estimates, of nutrient loads - flux (kg/yr), yields(kg/km^2/yr), and conc (mg/l) - in unmonitored stream reaches/watersheds in modeled region (e.g., New Eng, US)
- Used in TMDL and nutrient-criteria programs, tracking nutrient sources/delivery in Gulf of Mex., Chesapeake Bay, Long Island Sound Study, etc.

NE *SPARROW* Input



Nutrient Sources

Point Sources

Atm deposition of N (Ollinger,1992)

National Land Cover Dataset 1992
- Agriculture
- Urban
- Forest

Processes

Land to water delivery

Soil permeability – STATSGO

In-stream loss

Mean ann. streamflow
Reservoir detention

SPARROW
Estimated Equation

$$\text{Load}_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \underbrace{\beta_n \exp(-\alpha' Z_j)}_{\text{Land-to-water delivery}} \right] \underbrace{\exp(-\delta' T_{i,j})}_{\text{Instream decay}} \right\} \underbrace{\exp(\epsilon_i)}_{\text{Error}}$$

Load

Sources

Land-to-water delivery

Instream decay

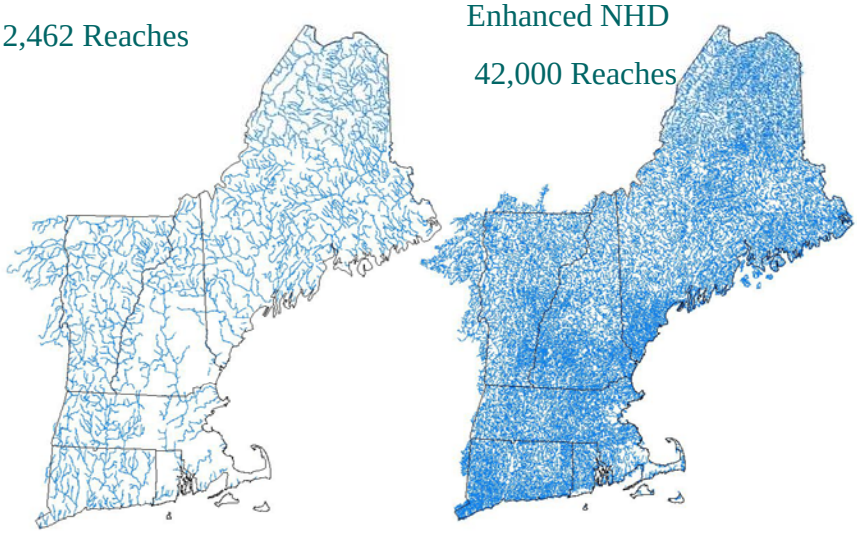
Error

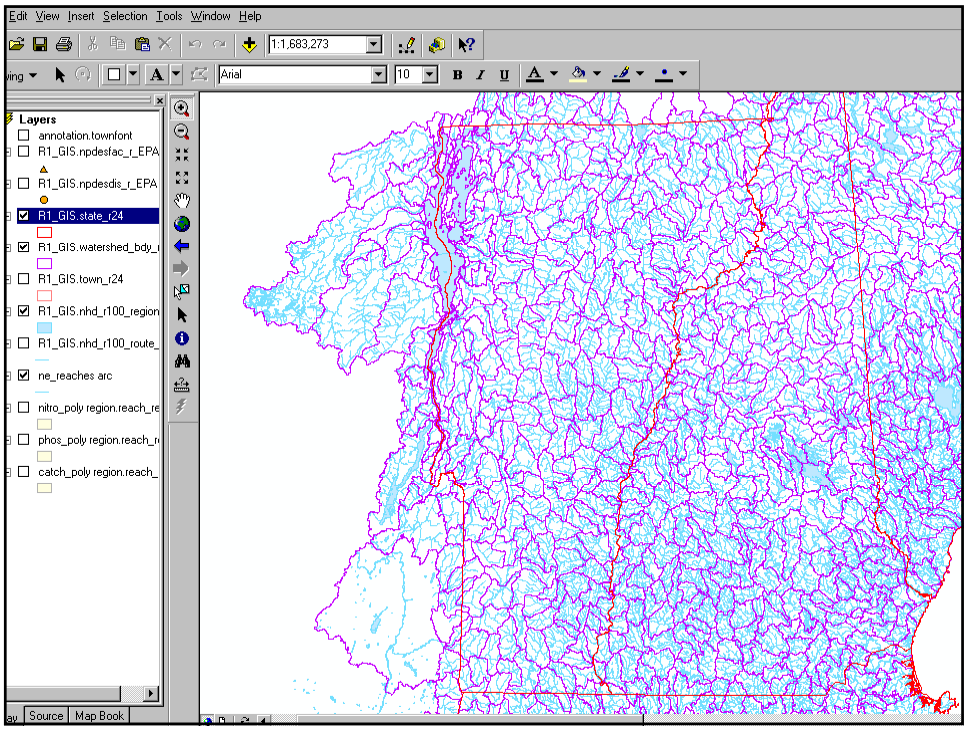
RF1

2,462 Reaches

NE *SPARROW*
Enhanced NHD

42,000 Reaches



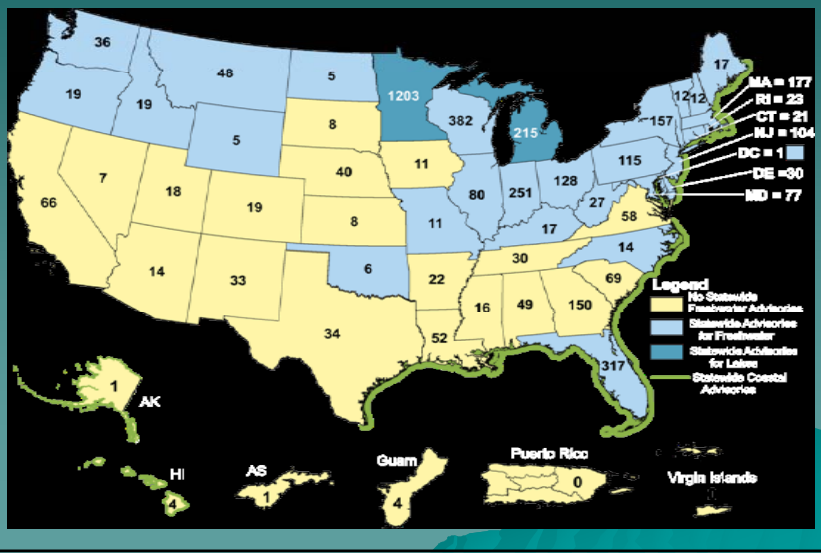


Modifying New England *SPARROW* for Mercury

- Key insights:
  - View fish-tissue (and piscivore) data from lake areas as dependent variable (analogous to data from WQ monitoring stations)
  - View mercury model as risk model rather than transport model – i.e., predict mercury levels in wildlife for any lake in New England

Fish Consumption Advisories – 2008

(EPA - National Fish and Wildlife Contamination Program

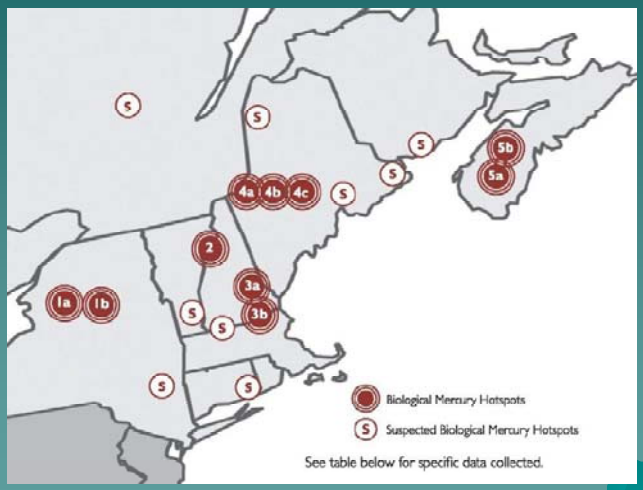


Mercury in freshwater fish
(Northeast North America)

- Four species with the highest mean Hg concentrations: muskellunge, walleye, white perch, and northern pike
- Waterbodies exceeding EPA criterion for fish Hg (0.3 ppm) ranged from 14% for standard-length brook trout fillets to 42% for standard-length yellow perch fillets.

[Source: Kamman et al., 2005 Ecotoxicology 14(1-2)]

Biological Mercury Hotspots (piscivores)



Evers et al. 2007. Biological mercury hotspots in the Northeastern United States and Southeastern Canada. Bioscience 57: 29-43

MERGANSER: Structure and Timeline

- MERcury Geo-spatial AssessmeNtS for the New England Region
- EPA ORD funding source –Advanced Monitoring Initiative. Grant awarded Dec 06; NESCAUM contract April 08
  - John Johnson, EPA-Athens, and I are co-P.O.s; John Graham is NESCAUM contract manager
  - Project team includes federal (EPA, USGS), interstate (NESCAUM), state (VT), and academic Hg researchers (BRI, ERG)
  - Projected model completion: June 2010
  - Products: reports, journal articles, web access

Alternative Model Forms

- (a) Standard multiple linear regression equation (least squares formulation)
- (b) “Multiplicative" model - explanatory variables separated into two types: mercury "source" and "process" variables
  - Source terms each multiplied by one or more process terms (factors that quantify transfer of mercury from each of sources to fish tissue)

MERGANSER estimated equation (multiplicative model)

$$M_i = \sum_{j=1}^{n} \beta_j S_{i,j} \left[\prod_{k=1}^{m} \exp\left(\lambda_{j,k} F_{i,k}\right) \right]$$

$$\ln M_i = \ln \left\{ \sum_{j=1}^{n} \beta_j S_{i,j} \left[\prod_{k=1}^{m} \exp\left(\lambda_{j,k} F_{i,k}\right) \right] \right\}$$

M_i = Mercury concentration (e.g. in yellow-perch equivalents) in lake i [M/V]

$S_{i,j}$ = Mercury source of type j, such as wet deposition rate [M/A/t] or amount of riparian wetland [L or A] , for lake i

β_j = source coefficient for source-type j

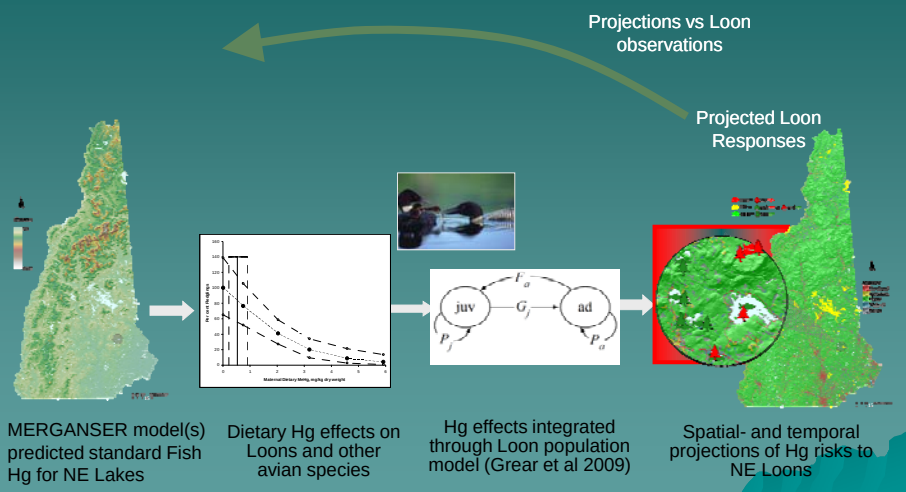
$F_{i,k}$ = transport or processing factor of type k, such as temperature or amount of riparian wetland, in lake i

$\lambda_{j,k}$ = coefficient relating source-type j to processing factor k

MERGANSER Response Variables

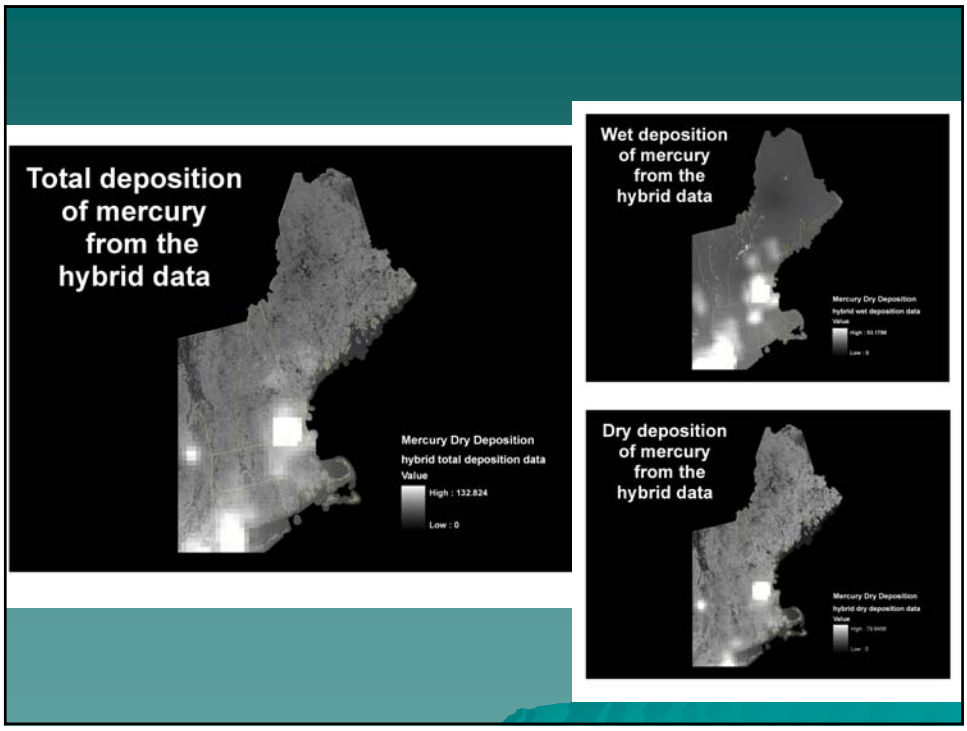
- Match fish data points to MERGANSER lakes
- Yellow Perch Equivalent (YPE): MERGANSER model(s) will predict mercury levels in standard fish units for New England Lakes (M_i)
  - Exploring inclusion of fish species and length
- Approaches for loons (possibly extend to other piscivores):
  - Direct conversion from YPE using empirical relations
  - Model using full predictor variable set

Mercury Risks to New England Loons

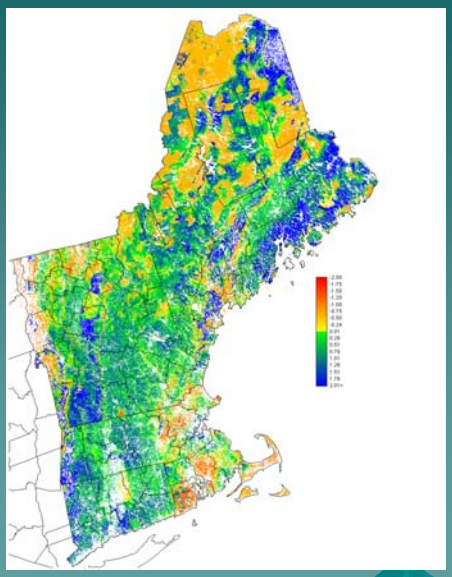


MERGANSER Predictor Variables

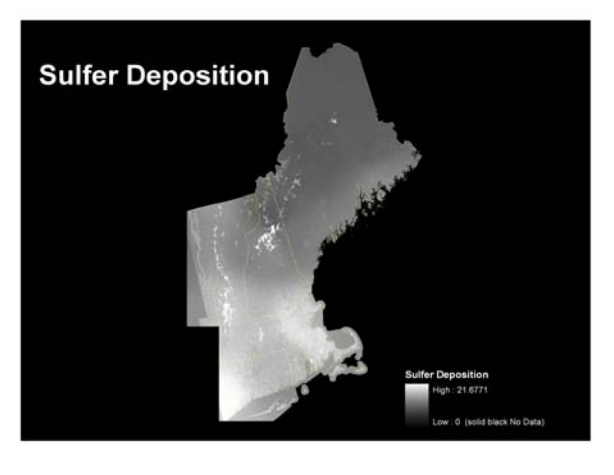
- Dry deposition breakdown (mercury form affects bioavailability)
- Total mercury deposition to lake
- pH (proxy)
- Sulfur deposition
- NWI wetlands categories
- Percent wetland area contiguous to lake
- SPARROW phosphorus
- Percent watershed as upgradient lake (=total “water” area minus lake area). Start at getting at nested lake issue


Total deposition of mercury from the hybrid data
Mercury Dry Deposition
hybrid total deposition data
Value
High : 132.824
Low : 0
Wet deposition of mercury from the hybrid data
Dry deposition of mercury from the hybrid data

pH Proxy



Sulfur Deposition



Public Database: Lake Quality and Fish/wildlife Mercury Data

http://www.epa.gov/aed/html/wildlife/index.html

MERGANSER Issues

- *Large lakes*
  - Divide into contributing watersheds? Problem: few lakes have fish Hg from multiple sites. (Large lakes generally have data so don't need model predictions)
  - For loons, much of data are from multiple territories on lake, so large-lake issue more pertinent
  - Lake Champlain won't include in model (would need too much data from outside New England)
- *Nested lakes*
  - At very least, flag them to evaluate their model residuals as a group

Current Focus

- USGS is completing independent variable set
- USGS is evaluating linear (least squares) and multiplicative modeling approaches
  - Identify key independent variables
- Evaluating "source additive" nonlinear model form (with source-specific multiplicative processing terms)
- Preliminary results of linear and multiplicative modeling will be presented at AGU conference in Dec 2009

Endpoints: Linking *MERGANSER* with policy

- MERGANSER will provide information about:
  - *Natural features* that contribute to mercury risk (e.g., watershed size, presence of wetlands, low pH)
  - *Human-influenced conditions* that can be modified for desired outcomes (e.g., location of mercury sources)
- Model outputs/products:
  - Mercury levels in standard fish units for New England lakes (possibly streams)
  - Projected mercury levels in piscivorous birds (possibly other piscivores)
  - "Ecological risk" metrics (e.g., for loons)
  - Optimal locations for long-term mercury monitoring (for National Mercury Monitoring Network)
  - Predicted "hotspots" of deposition and exposure (including those linked with specific sources)

For More Information…

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