MERGANSER:

Predicting Mercury Levels in Fish and Loons in New England Lakes

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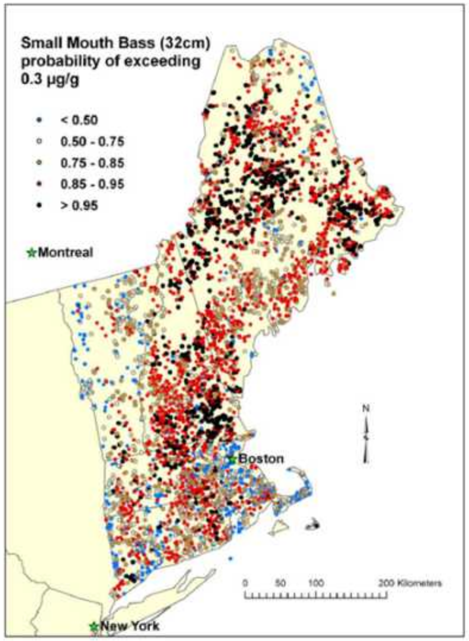
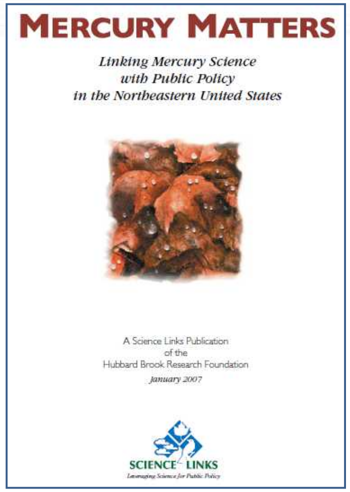
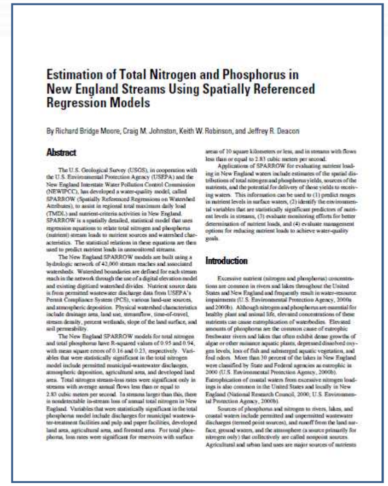


Cooperators:
USEPA
USGS
NESCAUM
NEIWPCC
State of Vermont DEC
BioDiversity Research Institute
Ecosystems Research Group

Presenting author: Neil Kamman, VTDEC

Genesis of *MERGANSER*





Estimation of Total Nitrogen and Phosphorus in New England Streams Using Spatially Referenced Regression Models

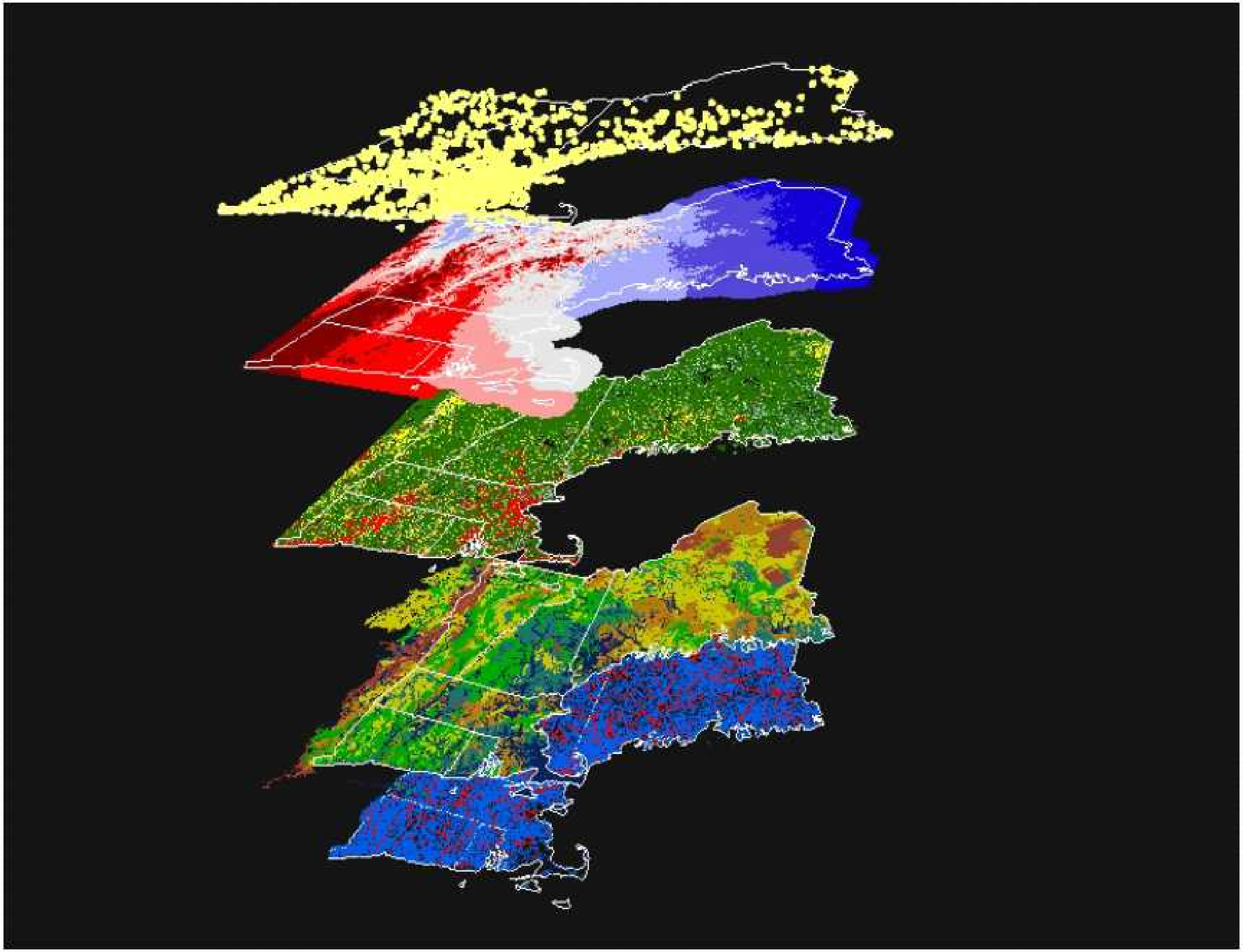
By Richard Bridge Moore, Craig M. Johnston, Keith W. Robinson, and Jeffrey R. Deacon

Abstract

Introduction

- SPARROW "Spatially Referenced Regressions on Watershed Attributes" - provides estimates <u>with uncertainty</u> of nutrient loadings in rivers (USGS, Smith et al, 1993 & 1997; Moore et al, 2004)
- Used in TMDL and nutrient-criteria programs, tracking nutrient sources/delivery in Gulf of Mex., Chesapeake Bay, Long Island Sound Study, etc.

Spatially Referenced Regressions on Watershed Attributes



MERGANSER: Main Objectives

- MERcury Geo-spatial AssessmeNtS for the New England Region
- Develop tool to improve knowledge of how Hg interacts with environment and to inform management response
- Use approach that maximizes use of available data on Fish & Loon Hg, Hg wet/dry deposition & landscape features
- Identify factors linked with spatial variation in Fish & Loon Hg and
- Provide estimates of Fish and Loon Hg (with error estimates) for as many lakes as possible in New England

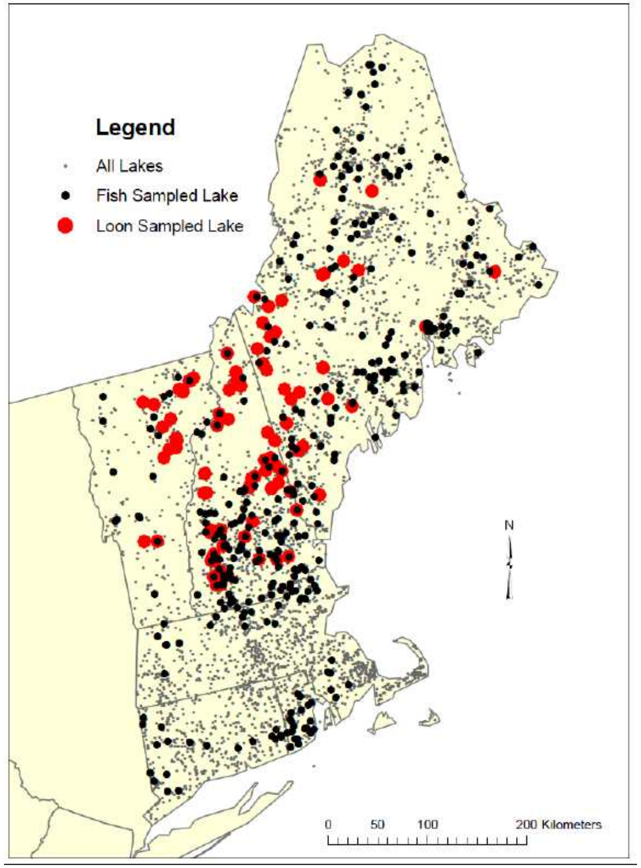
Project Team

- EPA: Alison Simcox (Region 1), Diane Nacci and Jane Copeland (AED), John Johnston (ORD) (Thanks also to Jeri Weiss)
- NESCAUM: John Graham, Kathleen Fahey (now Laura Shields)
- USGS: Jamie Shanley, Richard Moore, Craig Johnston, Keith Robinson, Richard Smith
- VT DEC: Neil Kamman
- Biodiversity Research Institute (BRI): David Evers, Kate Williams
- Ecosystems Research Group (ERG): Eric Miller
- NEIWPCC: Susy King

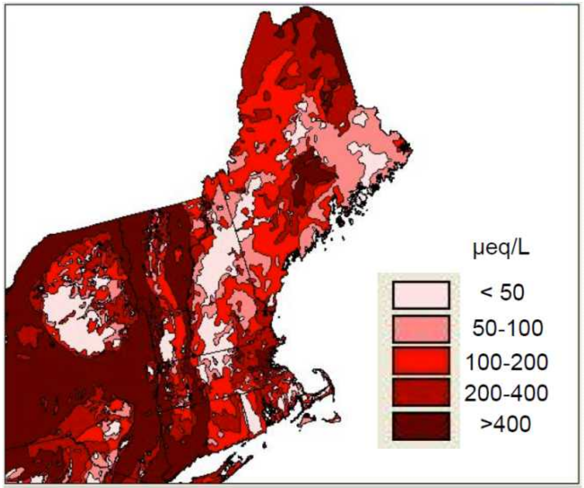
Modifying *SPARROW* for Mercury

- Model endpoints (dependent variables)
  - Fish Hg
  - Loon blood Hg
- Independent variables
  - Watershed characteristics
  - Water quality characteristics
  - Physical lake attributes
  - Deposition
- User-selections
  - Fish taxa and fish length
  - Hg reduction scenarios

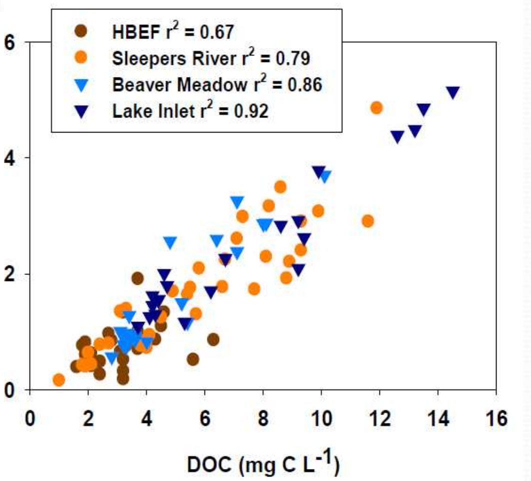
Lakes and proxies



4404 lakes modeled from 765 Lakes with data



Watershed-level alkalinity modeled in lieu of in-Lake pH



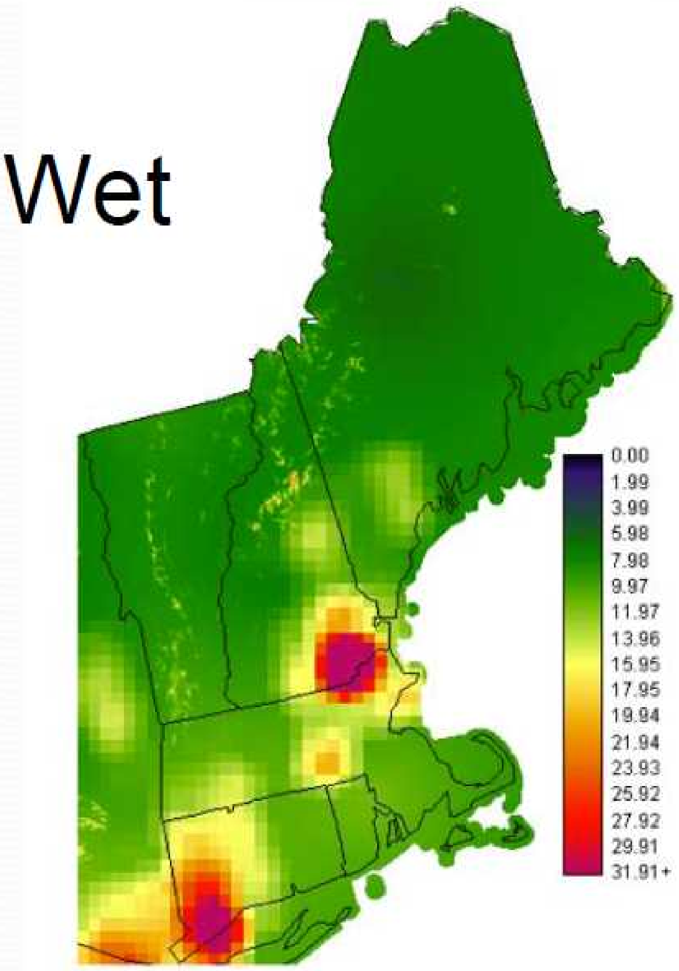
Wetland cover used as proxy for in-lake DOC

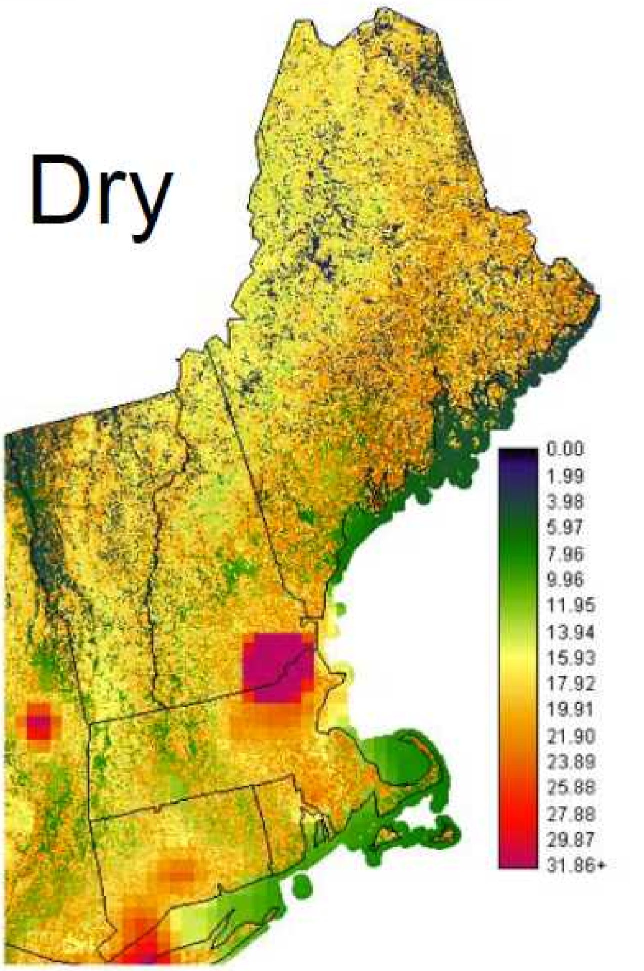
Hg Deposition model for MERGANSER

- Developed specifically for MERGANSER by Eric Miller, Ecosystems Research Group, Ltd., building from his earlier work.

- Hybrid of High-Resolution Deposition Model (HRDM) and Regulatory Modeling System for Aerosols and Deposition (REMSAD)

Modeled Hg wet and dry deposition





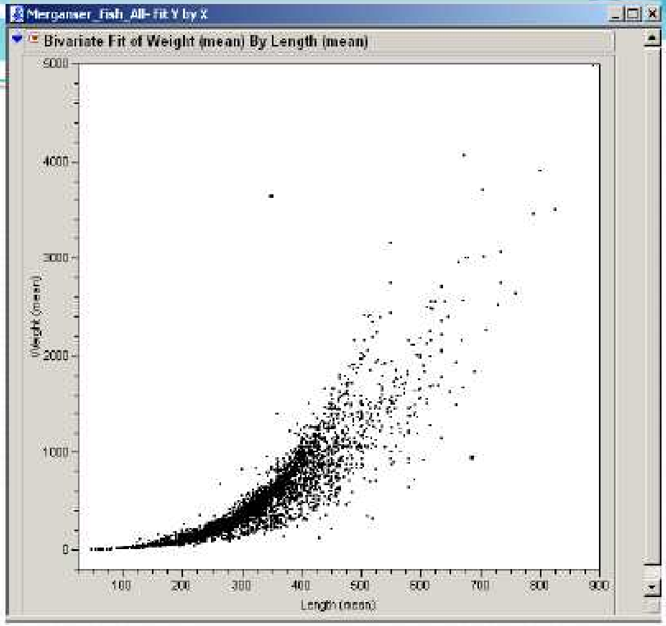
Core datasets

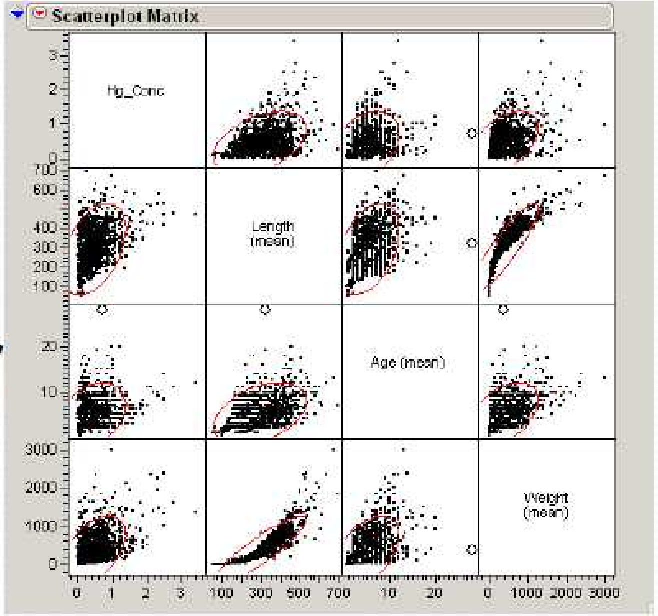
- NERC Dataset
  - Pre 2005
  - Northeastern North America
  - 16,000K records for NE States and Atlantic Provinces
  - Core dataset from which the NE Regional TMDL was calculated
  - 13 core taxa
- Additional State, and BioDiversity Research Institute data
- datasets
  - Post 2005
  - Compiled by EPA-ORD (Atlantic Ecology Division)

Fish Hg

Data screening

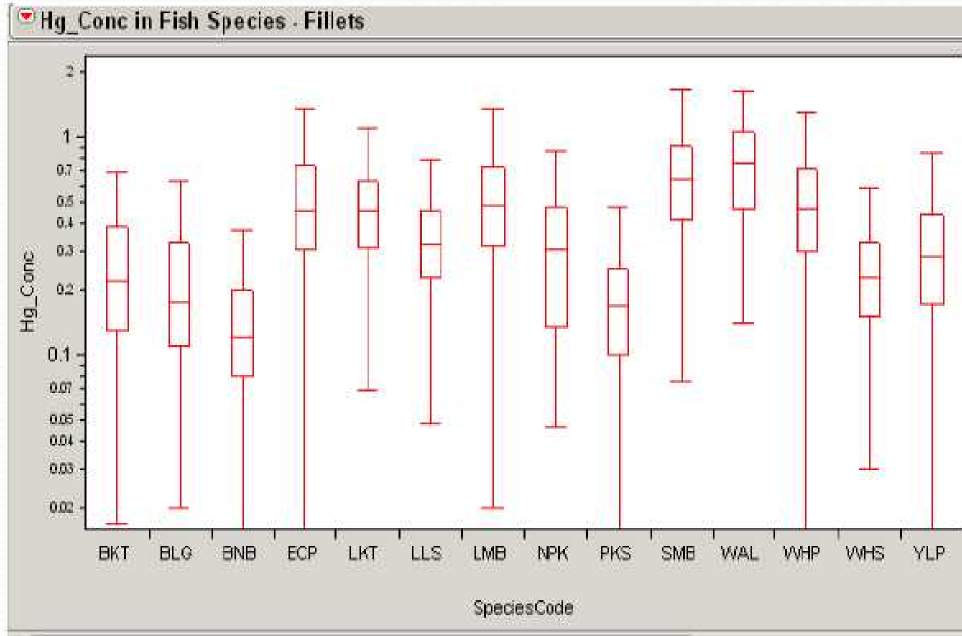
- Corrected units and retained only wet-weight
- Ensured validity of length / weight units and screened outlier data
- Examined length and weight / Hg plots to identify outliers
- Ensured accuracy/consistency of taxa codes





Fish Hg

- Highest [Hg] in walleye, pickerel, smallmouth bass
- Lowest [Hg] in bullhead, panfish
- Yellow perch intermediate in [Hg]
- Results consistent with prior studies, despite augmented data.

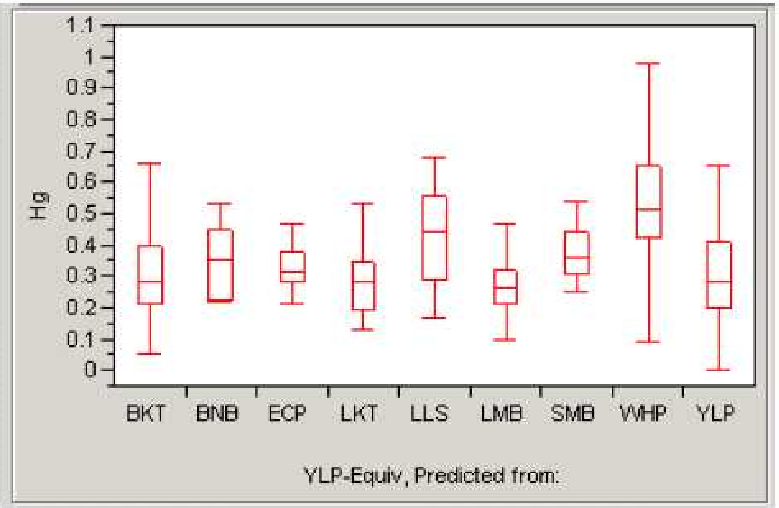


Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
BKT	0.017	0.07	0.13	0.2205	0.38925	0.555	0.94
BLG	0.02	0.05	0.11	0.175	0.3275	0.4881	0.63
BNB	0.01	0.0518	0.08	0.12	0.199	0.3218	1.264
ECP	0.01	0.1709	0.30825	0.462	0.739	1.1049	2.346
LKT	0.069	0.1481	0.3115	0.456	0.631	0.839	1.51
LLS	0.049	0.13	0.229	0.3225	0.4625	0.72	2.08
LMB	0.02	0.1958	0.318	0.484	0.73	1.1	2.645
NPK	0.047	0.0588	0.135	0.305	0.48	0.677	0.858
PKS	0.01	0.056	0.1	0.17	0.25	0.44	0.57
SMB	0.076	0.2608	0.419	0.637	0.92	1.32	3.41
WAL	0.14	0.185	0.465	0.76	1.06	1.345	1.62
WHP	0.01	0.17	0.29875	0.47	0.7135	0.91	2.2
WHS	0.03	0.0856	0.1495	0.229	0.3305	0.5598	1
YLP	0.01	0.1	0.171	0.282	0.44	0.628	4.308

Cross-taxa predictions

- Explored creating regressions to convert Hg in other taxa to standard yellow perch values
- Used these to produce length-adjusted standard yellow perch Hg for each lake in dataset.
- Cool analysis, but ultimately, these were not used in Merganser as individual taxa yielded higher variance explained in the model.



The "female loon unit" (FLU)

FLUs from male blood samples (n=278 for modeling)

Maine FLUs (Equation 1):

$FLU = \text{♀}Hg = (0.032112 + 0.81409\sqrt{\text{♂}Hg})^2$ 95% *CIs*: 0.727-0.909 $r = 0.80$

Other states' FLUs (Equation 2):

$FLU = \text{♀}Hg = (-0.27705 + 1.025411\sqrt{\text{♂}Hg})^2$ 95% *CIs*: 0.887-1.187 $r = 0.81$

FLUs from chick blood samples (6-8 weeks old; n=29)

$FLU = (0.467509 + 1.791596\sqrt{JuvHg})^2$ 95% *CIs*: 1.258-2.768 $r = 0.73$

The Merganser Model

Table 1. MERGANSER predictors and coefficient values, with standard error, t- and p-values, and variance inflation factors. Overall model r^2 was 0.63.

Predictor	Units	Coefficient	Standard error	t-value	p-value	Variance Inflation factor	Source(*1)
			Spatial variables				
Intercept		-11.1270	0.463	-24.03	<0.0001	0.00	
ln (total Hg deposition)	$\mu g\ m^{-2}\ yr^{-1}$	0.2773	0.046	6.00	<0.0001	4.06	Miller et al. (2005); this paper
ln (watershed area)	km^2	0.0354	0.006	5.90	<0.0001	2.24	NHDPlus
ln (% forest canopy area)	%	0.2400	0.085	2.83	0.0047	6.49	NLCD
ln (% wetland area)	%	0.0666	0.012	5.60	<0.0001	2.01	NWI
4th root of population density, 2000 Census	km^{-2}	0.0514	0.008	6.16	<0.0001	2.33	NHDPlus
ln (slope)	unitless: y/x	-0.1400	0.032	-4.32	<0.0001	3.15	NHDPlus
ln (mean annual temperature, 1971-2000)	degrees C (°C)	-0.4446	0.057	-7.83	<0.0001	5.51	NHDPlus
ln (% agricultural land)	%	0.0198	0.007	2.86	0.0042	1.92	NLCD
weighted watershed alkalinity	unitless(*3)	-0.1207	0.009	-13.17	<0.0001	1.68	EPA
Interaction term: % shrubland and ln (total Hg deposition)		0.0092	0.001	9.26	<0.0001	2.05	NLCD, Miller et al. (2005)
Interaction term: % forest canopy and ln (total Hg deposition)		0.0035	0.000	7.46	<0.0001	9.32	NLCD, Miller et al. (2005)
Interaction term: ln (total Hg deposition) and watershed alkalinity(*2)		0.1928	0.027	7.06	<0.0001	1.93	Miller et al. (2005), EPA
			User-input variables				
Loon	binary: 1/0	9.4821	0.202	46.83	<0.0001	37.36(*4)	User specified
ln (length)	mm	1.5310	0.036	42.24	<0.0001	39.95(*4)	User specified
ln (length): brook trout	mm	-0.1337	0.010	-13.78	<0.0001	1.63	User specified
ln (length): brown bullhead	mm	-0.1846	0.007	-24.97	<0.0001	1.14	User specified
ln (length): eastern chain pickerel	mm	-0.0720	0.008	-8.99	<0.0001	1.25	User specified
ln (length): lake trout	mm	-0.1716	0.008	-21.14	<0.0001	1.94	User specified
ln (length): land locked salmon	mm	-0.1600	0.010	-15.76	<0.0001	1.26	User specified
ln (length): largemouth bass	mm	-0.0150	0.005	-3.15	0.0016	1.87	User specified
ln (length): pumpkinseed	mm	-0.0362	0.012	-2.90	0.0037	1.10	User specified
ln (length): white perch	mm	0.0457	0.006	8.07	<0.0001	1.30	User specified
ln (length): white sucker	mm	-0.2292	0.013	-17.76	<0.0001	1.15	User specified

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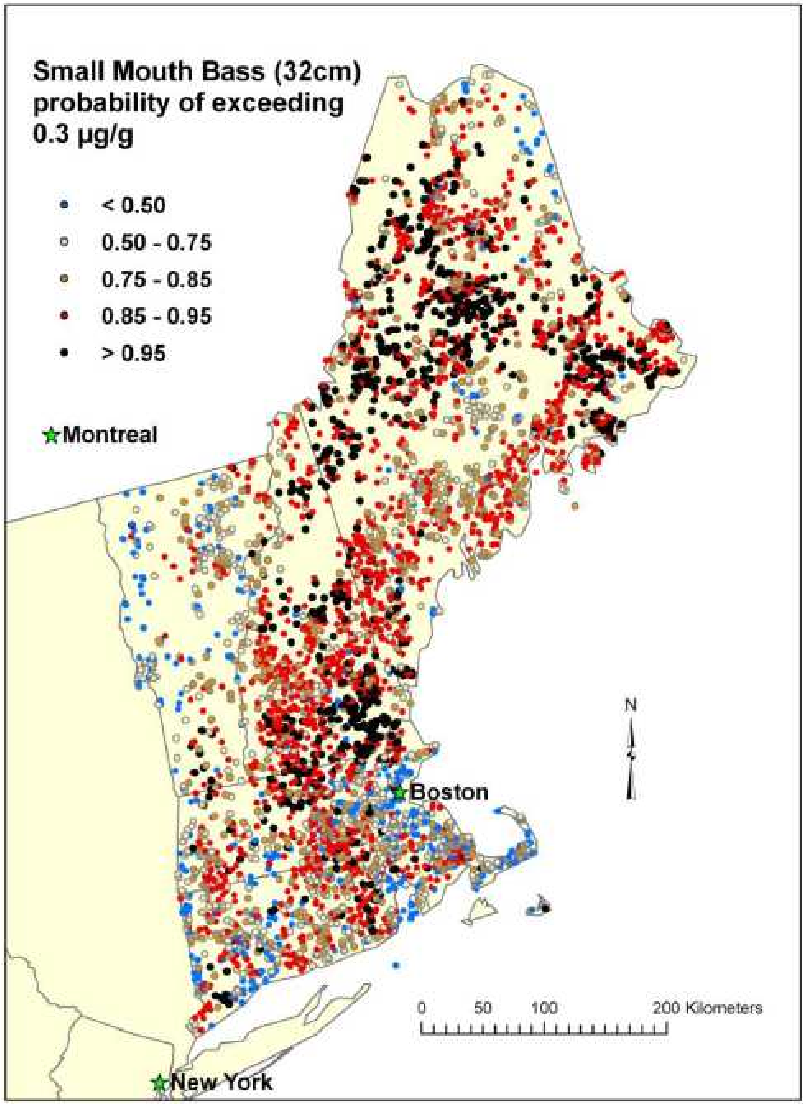
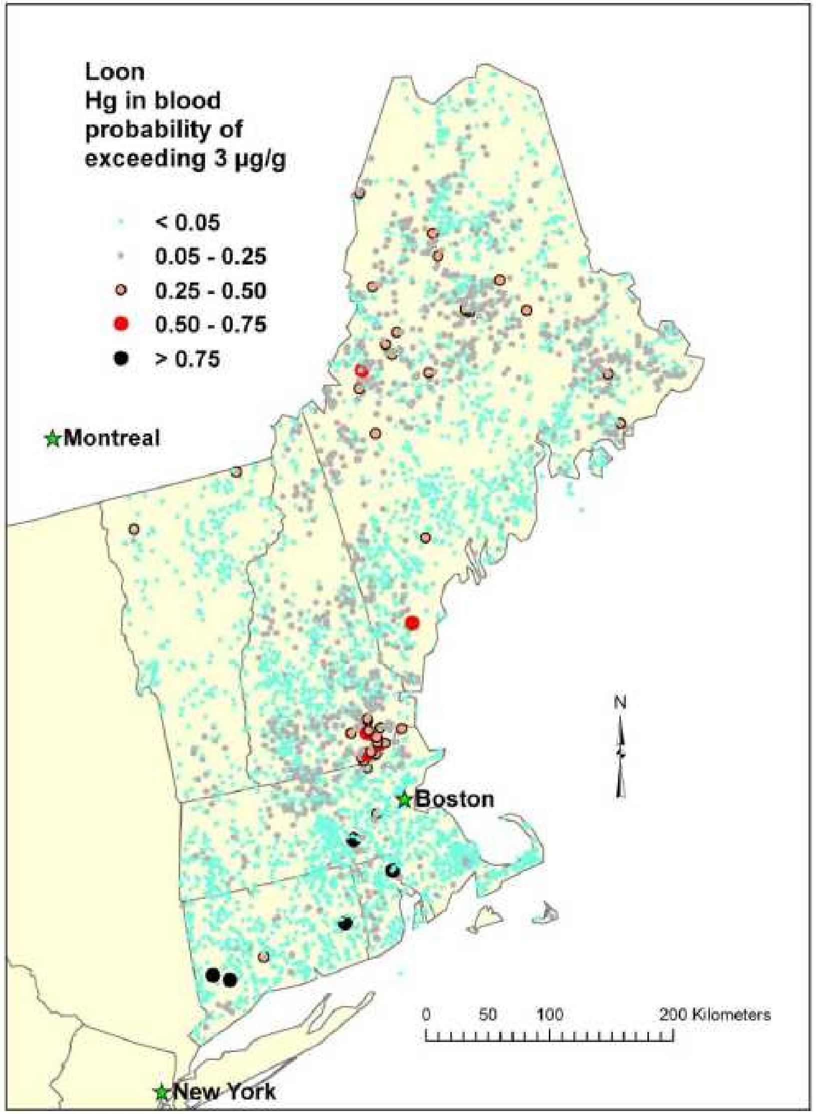
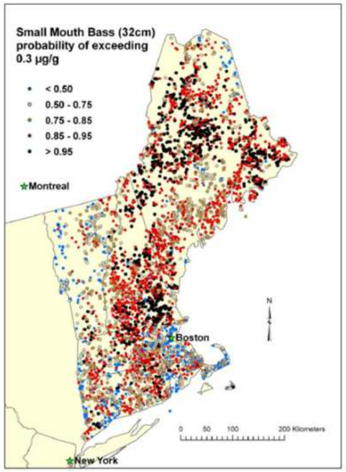
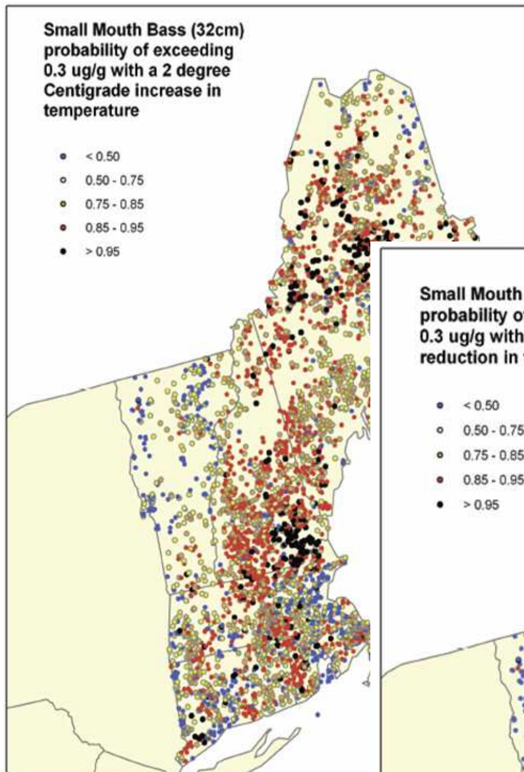
Smallmouth bass (32-cm) probability plot

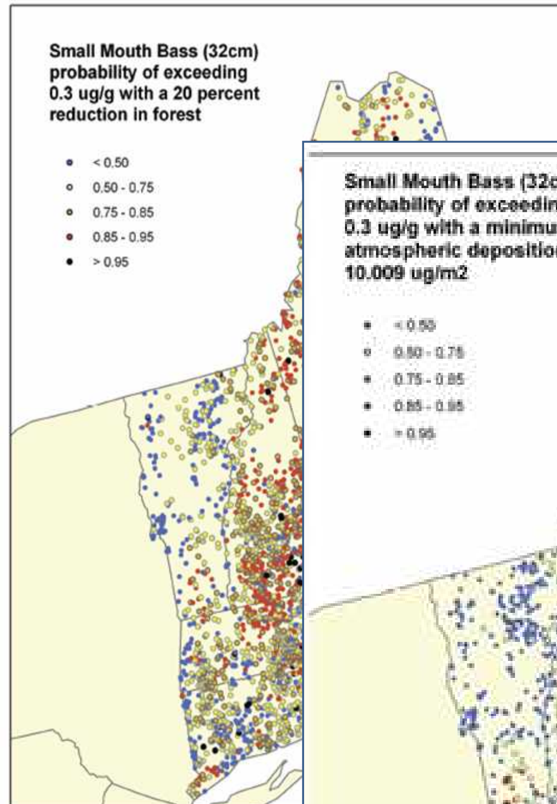


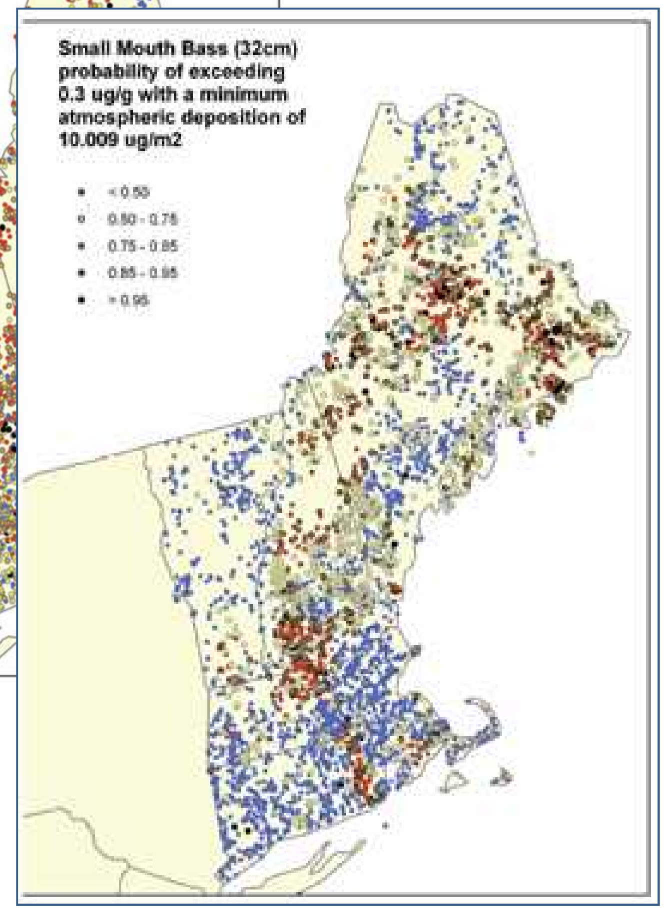
Loon Probability Plot







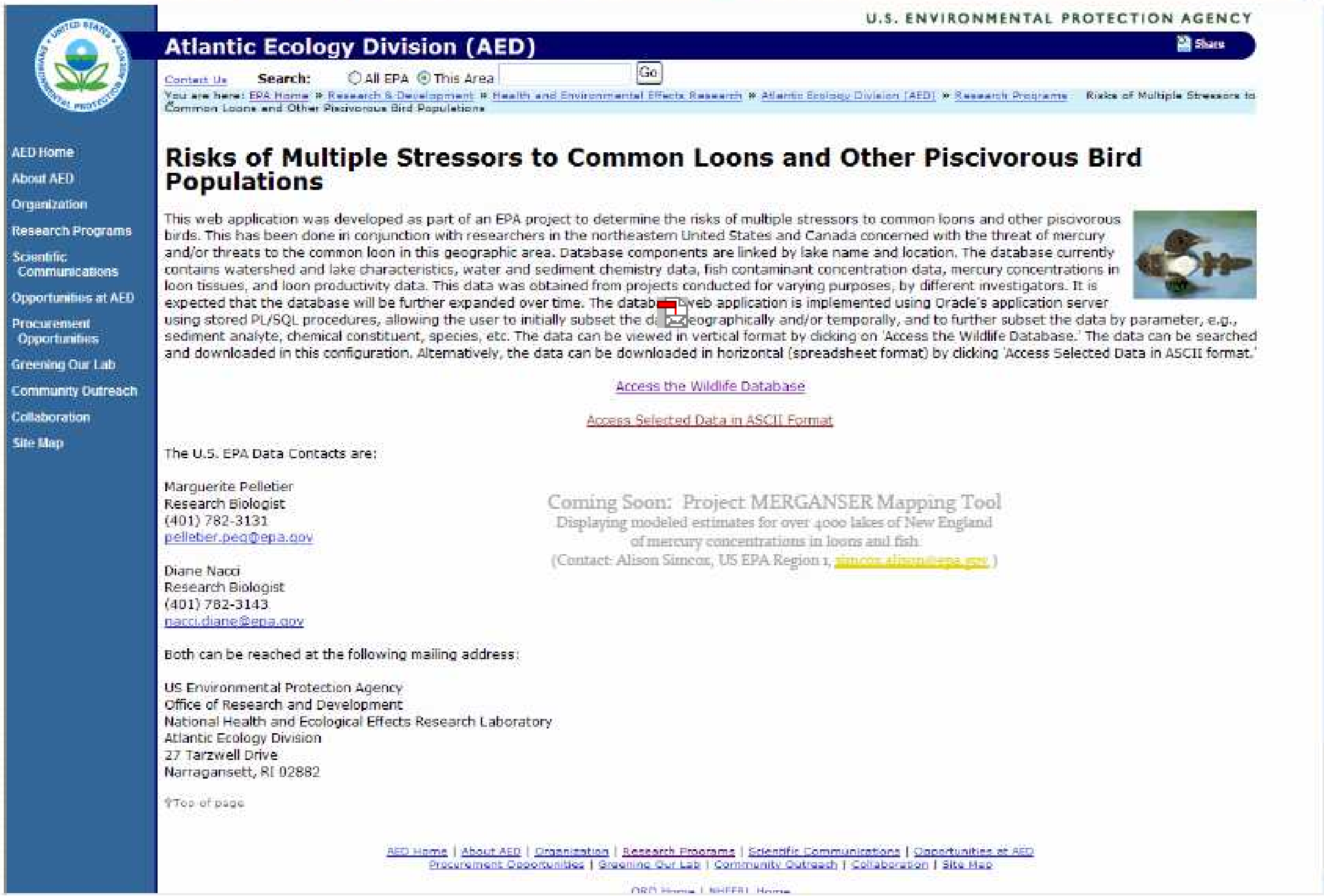




Scenario Testing

EPA's Wildlife Risk Project

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



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Risks of Multiple Stressors to Common Loons and Other Piscivorous Bird Populations

This web application was developed as part of an EPA project to determine the risks of multiple stressors to common loons and other piscivorous birds. This has been done in conjunction with researchers in the northeastern United States and Canada concerned with the threat of mercury and/or threats to the common loon in this geographic area. Database components are linked by lake name and location. The database currently contains watershed and lake characteristics, water and sediment chemistry data, fish contaminant concentration data, mercury concentrations in loon tissues, and loon productivity data. This data was obtained from projects conducted for varying purposes, by different investigators. It is expected that the database will be further expanded over time. The datab[illegible]web application is implemented using Oracle's application server using stored PL/SQL procedures, allowing the user to initially subset the da[illegible]eographically and/or temporally, and to further subset the data by parameter, e.g., sediment analyte, chemical constituent, species, etc. The data can be viewed in vertical format by clicking on 'Access the Wildlife Database.' The data can be searched and downloaded in this configuration. Alternatively, the data can be downloaded in horizontal (spreadsheet format) by clicking 'Access Selected Data in ASCII format.'

Access the Wildlife Database

Access Selected Data in ASCII Format

The U.S. EPA Data Contacts are:

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Both can be reached at the following mailing address:

US Environmental Protection Agency
Office of Research and Development
National Health and Ecological Effects Research Laboratory
Atlantic Ecology Division
27 Tarzwell Drive
Narragansett, RI 02882

Coming Soon: Project MERGANSER Mapping Tool
Displaying modeled estimates for over 4000 lakes of New England
of mercury concentrations in loons and fish
(Contact: Alison Simcox, US EPA Region 1, [illegible])

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Future Steps and Uses

•Incorporating specific water quality variables will improve predictions, but to the detriment of expanded predictability

•Incorporation of predictions into next targeted sampling – target 'low probability of exceedance' lakes.

•Consider application of MERGANSER to other data rich areas, but with mindfulness that watershed processes vary tremendously across the US.