A dynamic model using monitoring data and watershed characteristics to project fish tissue mercury concentrations

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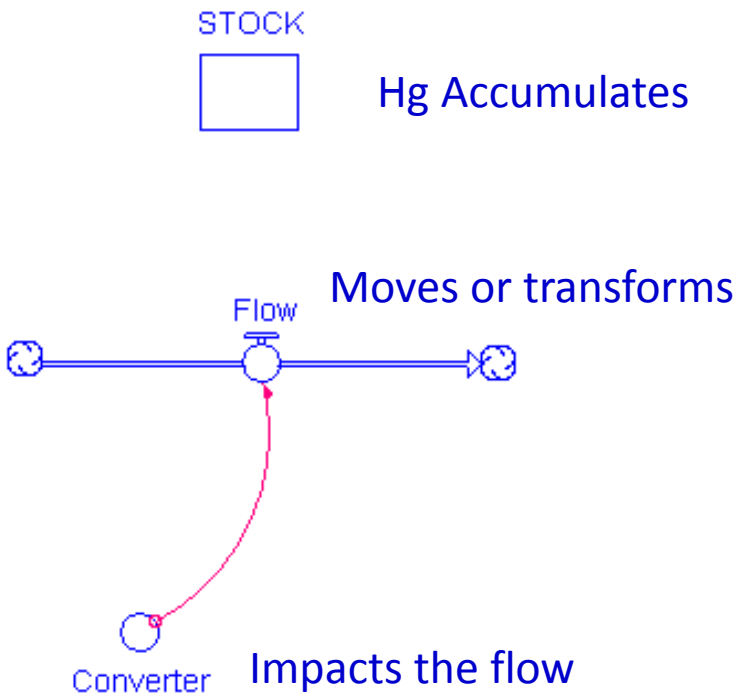
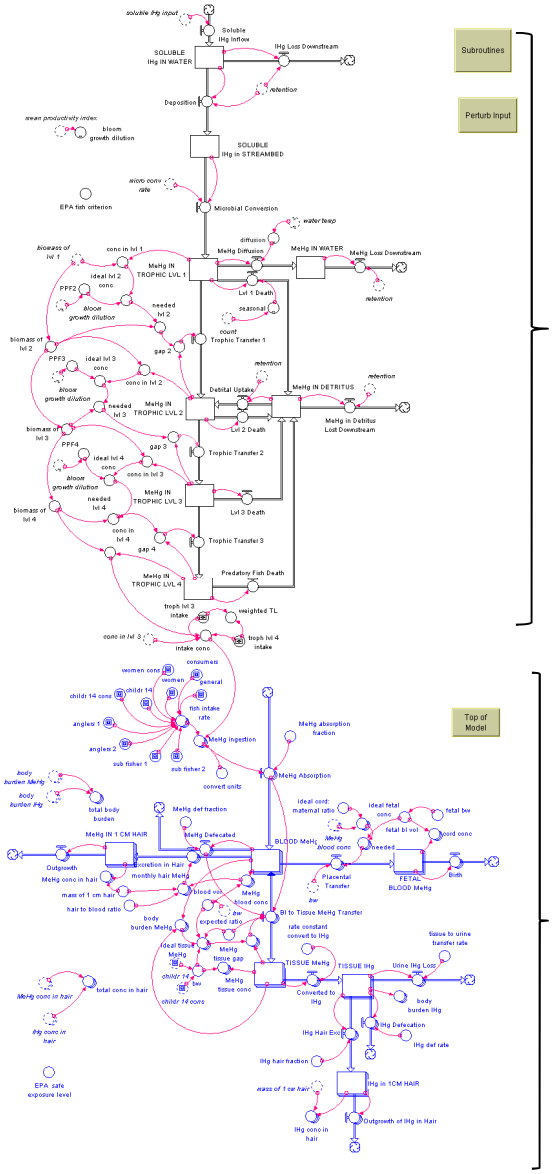
Purpose

1. Develop a model to predict fish tissue Hg levels based on site-specific parameters that influence bioaccumulation.
2. Gain understanding of the system that moves mercury through environmental compartments to the point of human exposure.
3. To be a tool for decision makers in assessing possible policy choices.

STELLA modeling tool

- Depicts systems in graphical form
- Gain understanding of relationships between the components of the system





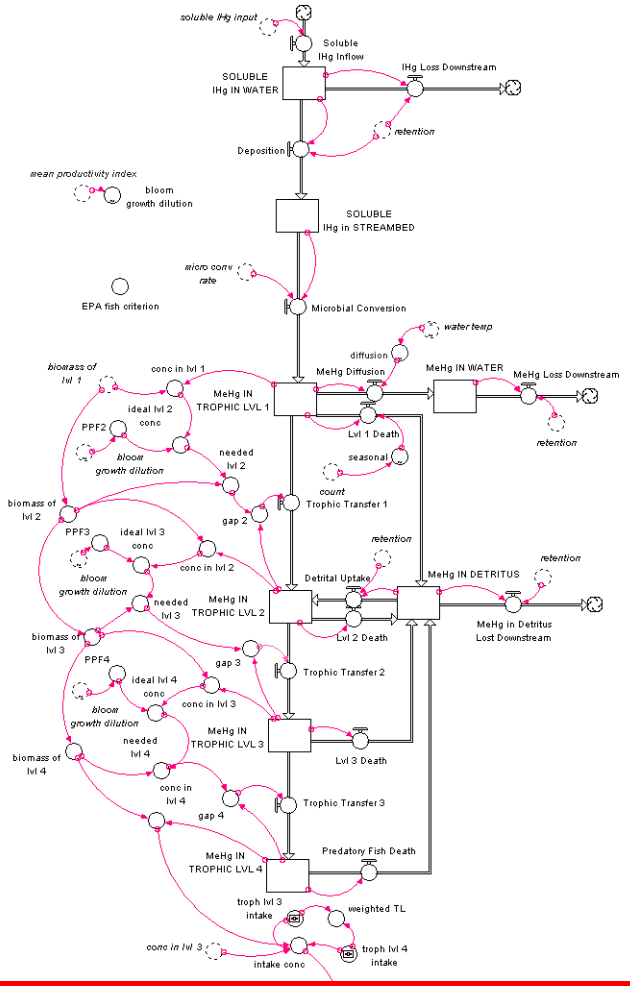
Bioaccumulation model

Population biomarkers model

Impact of policy scenarios on susceptible populations

Bioaccumulation Model

- Takes Hg from water column to concentration in generic trophic level 3-4 “quality” length fish
- Ohio River Valley
- Uses readily available land cover and monitoring data



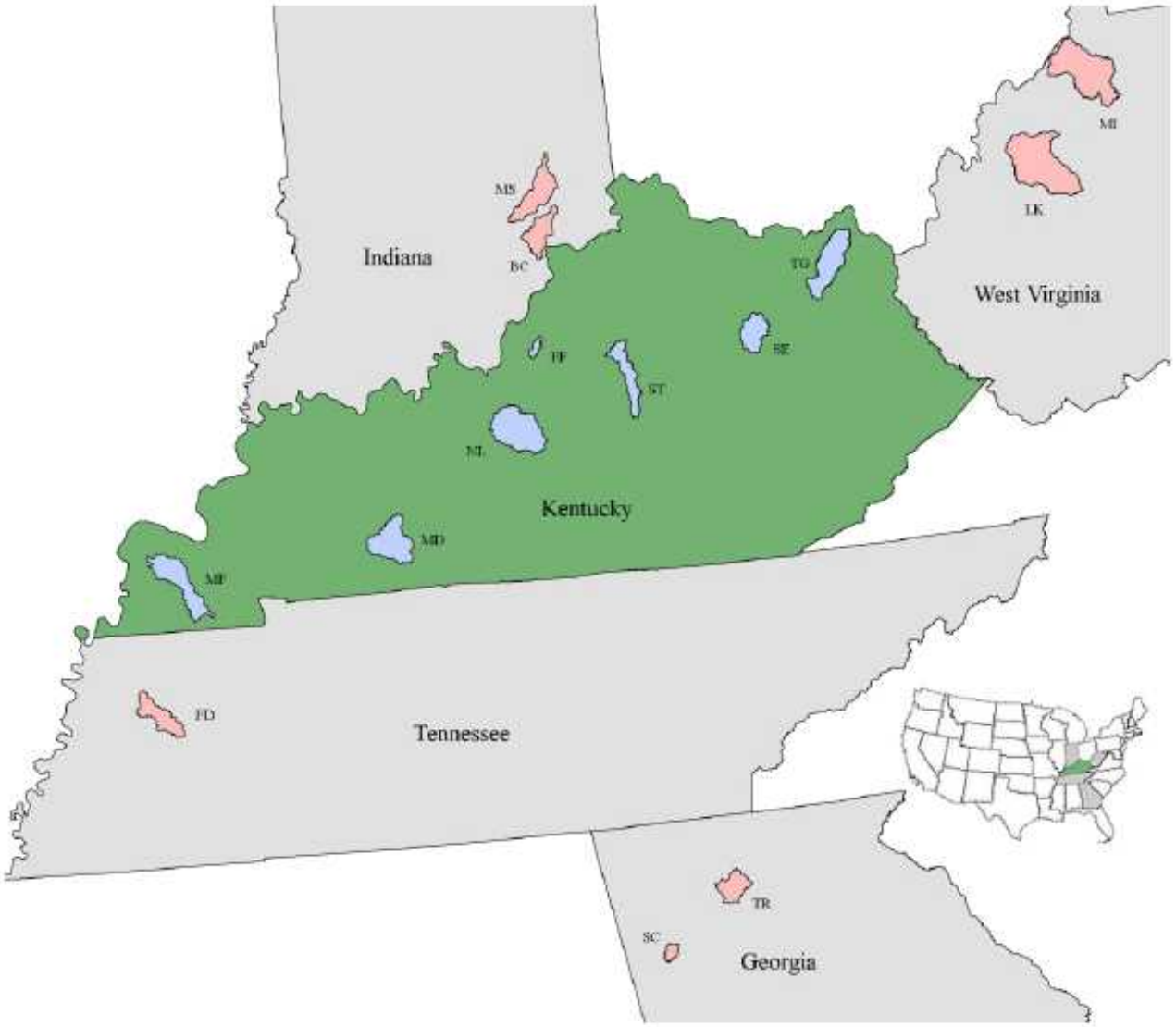
Input variables through linked Excel file

Single values

- Fraction forested
- Fraction wetlands
- Fraction developed
- Mean flow
- Watershed area
- Sinuosity
- Mean annual phosphorus
- Mean day length

Monthly means

- Flow
- THg concentration
- pH
- Phosphorus
- Water temperature
- Frequency of high precipitation
- Day length



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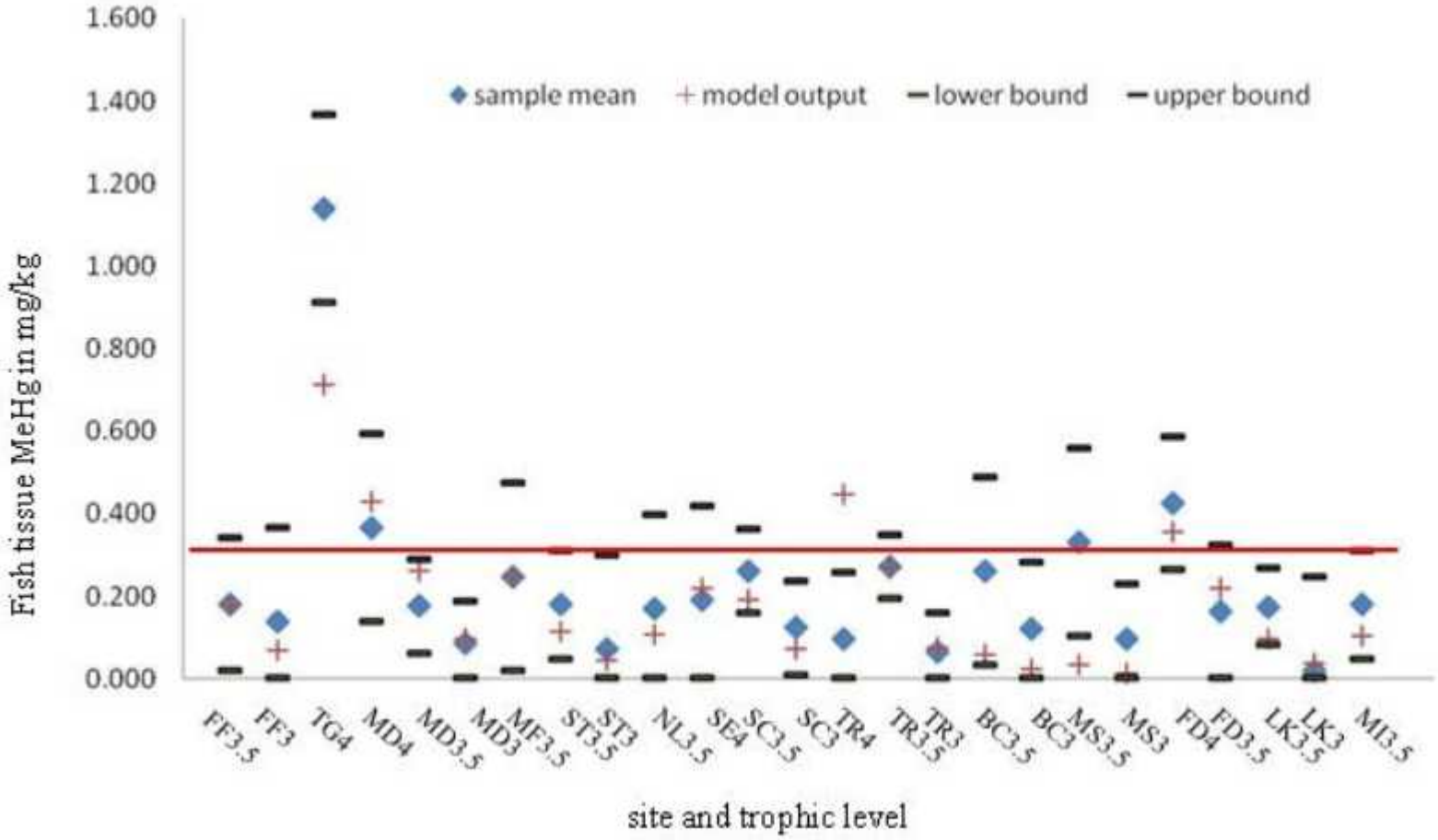
Site characteristics

Site	Site Abbr	Area km2	Mean annual Q m3/s	Mean pH	Mean P mg/l	fraction forested	fraction developed	fraction wetlands	Sinuosity
Calibration Sites[a]									
Floyds Fork	FF	70	1.0	7.79	0.1920	0.359	0.375	0.006	1.81
Mayfield Creek	MF	759	12.2	6.96	0.1972	0.234	0.064	0.042	1.00
Mud River	MD	689	11.1	7.37	0.0607	0.497	0.059	0.007	2.00
Nolin	NL	930	14.1	7.46	0.2139	0.246	0.093	0.000	1.59
Salt River	ST	451	7.2	8.03	0.2889	0.244	0.088	0.000	2.13
Slate Creek	SE	399	5.7	7.85	0.1005	0.343	0.027	0.000	1.44
Tygarts Creek	TG	720	8.8	7.63	0.0193	0.688	0.078	0.000	1.60
Evaluation Sites									
Big Creek, IN	BC	220	2.1	8.06	0.0704	0.099	0.092	0.000	1.48
Little Kanawha River, WV	LK	1448	17.0	7.32	0.2085	0.857	0.051	0.000	1.40
Middle Island Creek, WV	MI	1282	16.1	7.36	0.2085	0.877	0.046	0.000	1.25
Muscatatuck River, IN	MS	733	8.0	8.05	0.1506	0.471	0.050	0.000	1.19
North Fork Forked Deer River, TN	FD	448	5.2	6.85	0.2141	0.162	0.077	0.095	1.06
Spring Creek, GA	SC	98	1.4	8.07	0.0796	0.477	0.072	0.005	1.21
Talking Rock Creek, GA	TR	738	8.1	7.83	0.0441	0.796	0.064	0.003	1.25

Abbr = abbreviations, Q = discharge, P = Phosphorus

[a]All calibration sites are in Kentucky

Uncertainty around the sample mean of fish tissue Hg for site and trophic level combinations. The 95% confidence interval is based on an analysis of the National Fish Database.

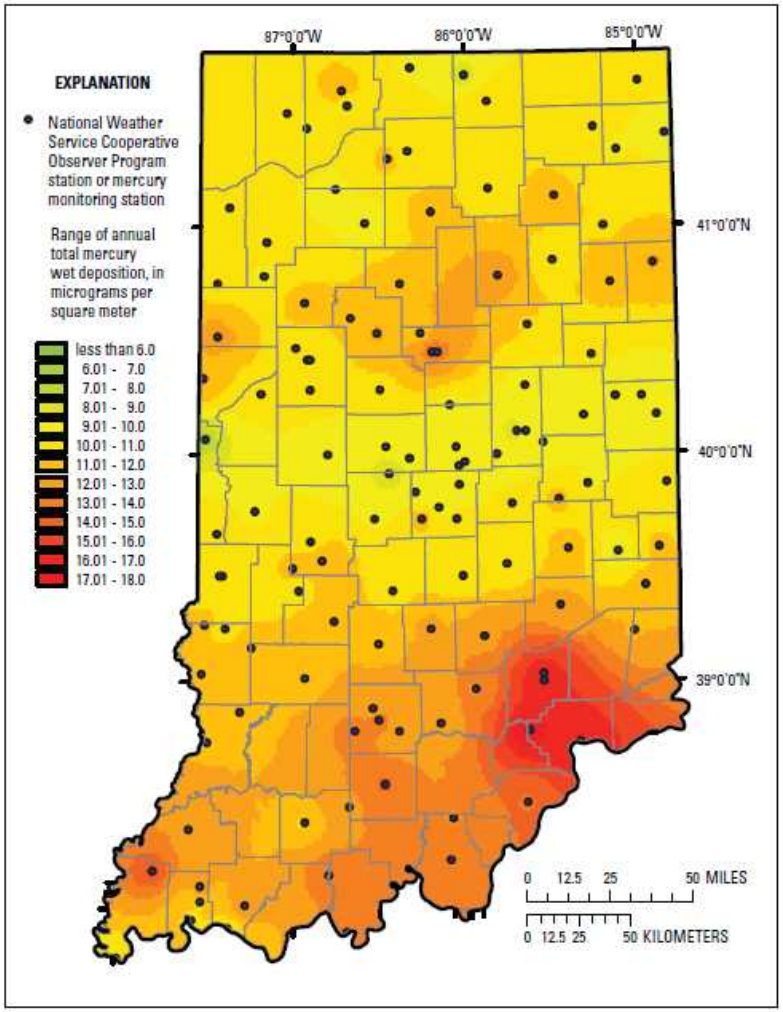


Fish tissue Hg (mg/kg) of sample mean with 95% confidence interval compared to model output and calculated prediction error.

Error calculation			95% CI			
Site	TL	sample	lower	upper	model	error
Calibration sites						
FF	3.5	0.179	0.018	0.340	0.177	0.01
FF	3	0.138	0.000	0.365	0.068	0.51
MD	4	0.366	0.139	0.593	0.430	0.17
MD	3.5	0.176	0.062	0.290	0.260	0.48
MD	3	0.085	0.000	0.186	0.096	0.13
MF	3.5	0.247	0.020	0.474	0.248	0.00
ST	3.5	0.179	0.048	0.310	0.114	0.36
ST	3	0.073	0.000	0.300	0.045	0.38
NL	3.5	0.170	0.000	0.397	0.106	0.38
SE	4	0.190	0.000	0.417	0.217	0.14
					MEAN	**0.26**

	Trophic Level		
	3	**3.5**	**4**
Calibration sites	0.34	0.25	0.16
Evaluation sites	0.65	0.38	0.17

Error calculation			95% CI			
Site	TL	sample	lower	upper	model	error
Evaluation sites						
SC	3.5	0.262	0.160	0.364	0.191	0.27
SC	3	0.123	0.009	0.237	0.071	0.42
TR	3.5	0.271	0.195	0.347	0.268	0.01
TR	3	0.065	0.000	0.158	0.076	0.17
BC	3.5	0.260	0.033	0.487	0.057	0.78
BC	3	0.120	0.000	0.281	0.022	0.82
MS	3.5	0.330	0.103	0.557	0.033	0.90
MS	3	0.097	0.000	0.228	0.012	0.88
FD	4	0.426	0.265	0.587	0.355	0.17
FD	3.5	0.162	0.001	0.323	0.217	0.34
LK	3.5	0.174	0.081	0.267	0.096	0.45
LK	3	0.018	0.000	0.245	0.035	0.94
MI	3.5	0.179	0.048	0.310	0.103	0.42
					MEAN	**0.51**



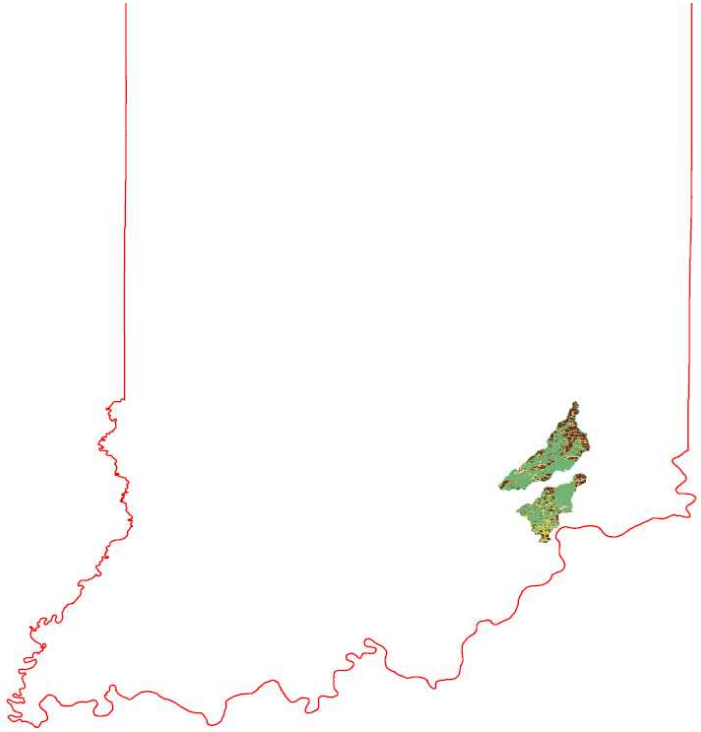
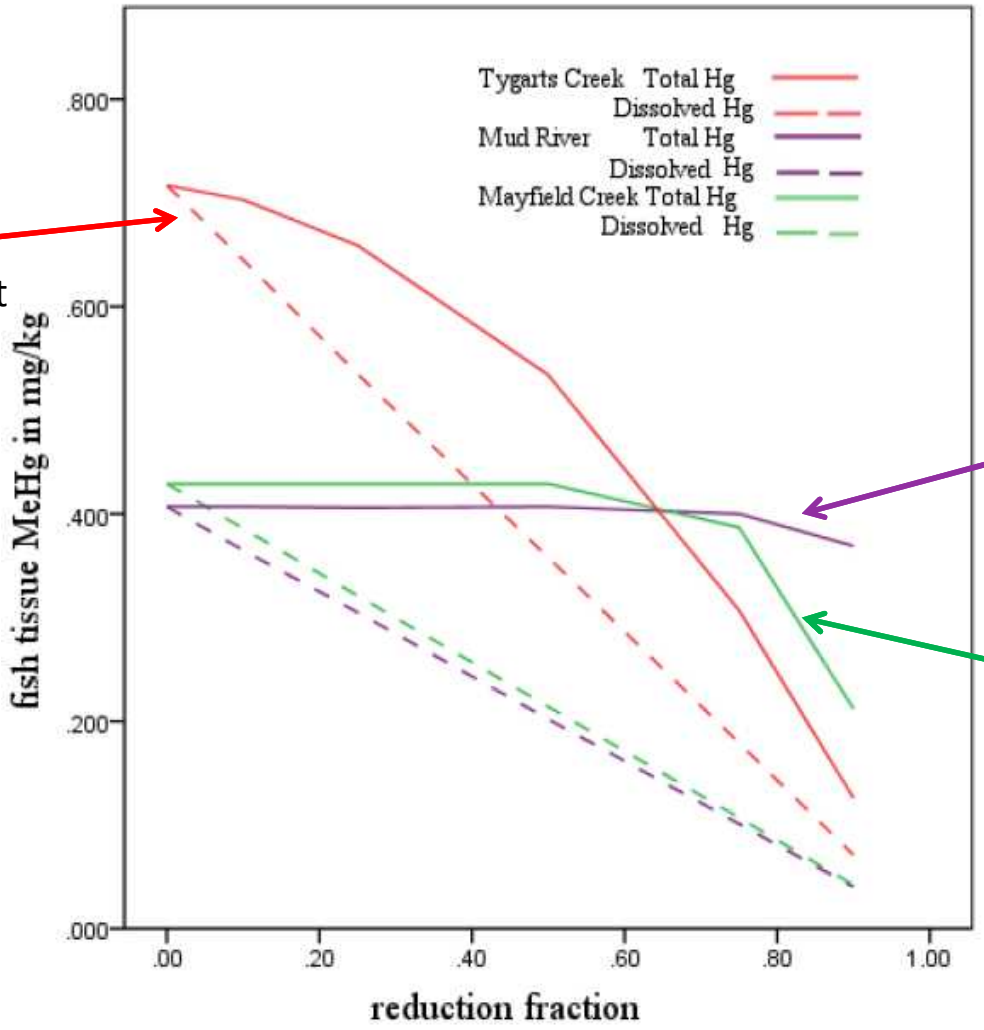


Figure 19. Isopleth map of annual wet deposition of mercury in Indiana in 2004.

Risch, M.R., and Fowler, K.K, 2008, Mercury in precipitation in Indiana, January 2004–December 2005: U.S. Geological Survey Scientific Investigations Report 2008–5148, 76 p.

High forested coverage, no wetlands, lowest nutrients



Mean THg

1.43 ng/l

3.40 ng/l

7.30 ng/l

Mix agriculture, forest, grassland; low wetlands, medium nutrients

High agriculture, 4% wetlands, high nutrients

Sensitivity of model output to reductions in total and dissolve Hg for three basins representing a range of land cover characteristics.

Land cover and bioaccumulation

- Land cover determines bioaccumulation and bioaccumulation efficiency
  - High wetlands and forested coverage ↑
  - High nutrients ↓
- What about unmeasured parameters?
  - DOC
  - Wet deposition
- System more sensitive to parameters that impact the structure at more than one place
- Targeting efficient systems for Hg reduction would have biggest impact

Strengths

- Model specifically for a region that is under-represented in the literature
- Increases understanding of stream systems
- Uses existing regulatory/monitoring data
- Applicable to basins with a range of land cover and uses

Limitations

- Limited evaluation of watersheds with significant wetlands
- Dissolved Hg data generally not available as input
- Uncertainty—natural and structural

What next?

- Water column mercury: loading
  - Wet deposition
    - Have information at the regional level
    - What would basin level wet deposition data tell us?
- Further evaluation of model with basins with a wider range of wetlands coverage
- Web-based program to increase accessibility