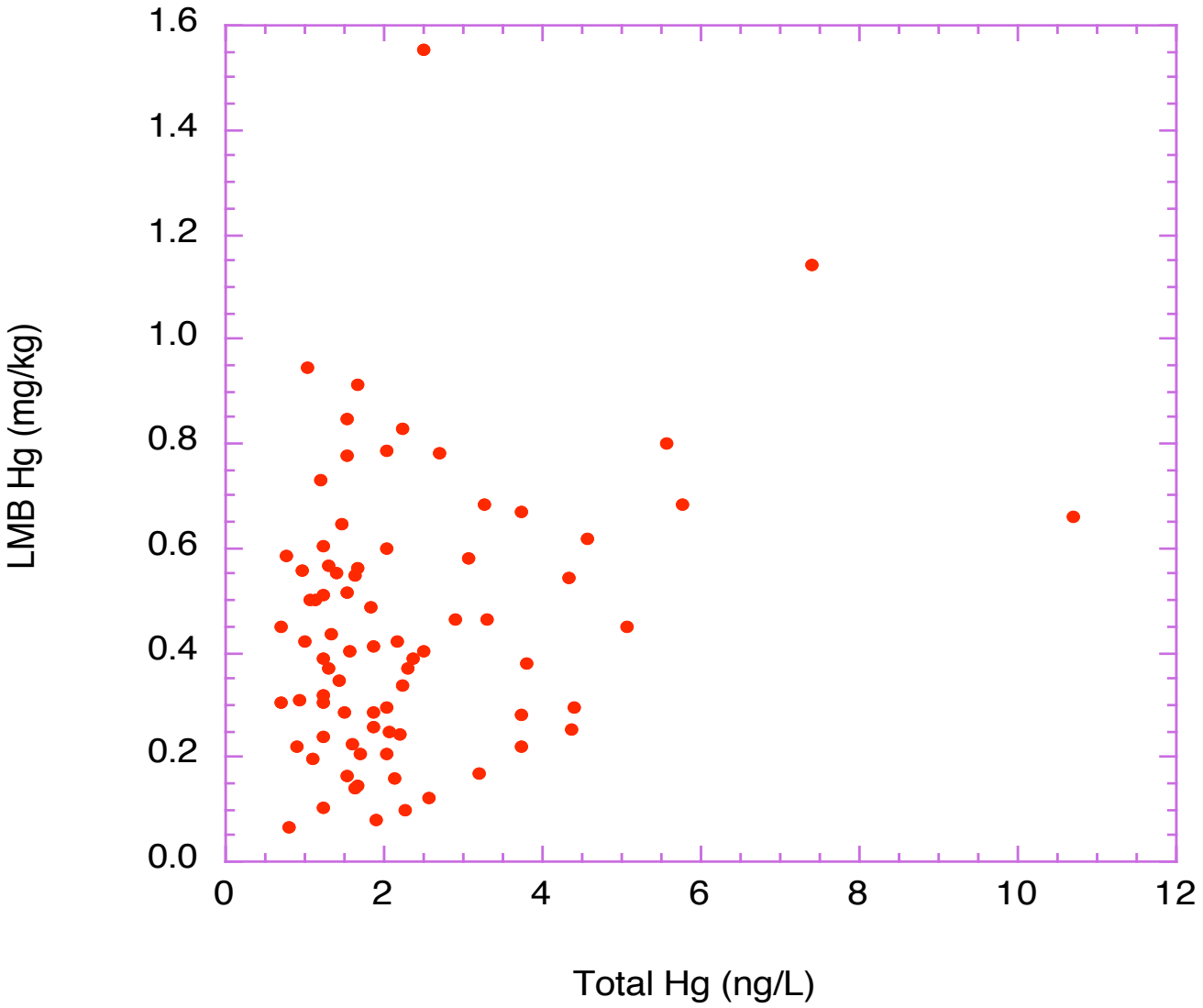
Linking Hg Deposition to Fish Tissue Hg Concentrations

Linking Hg Deposition to Fish Tissue Hg Concentrations

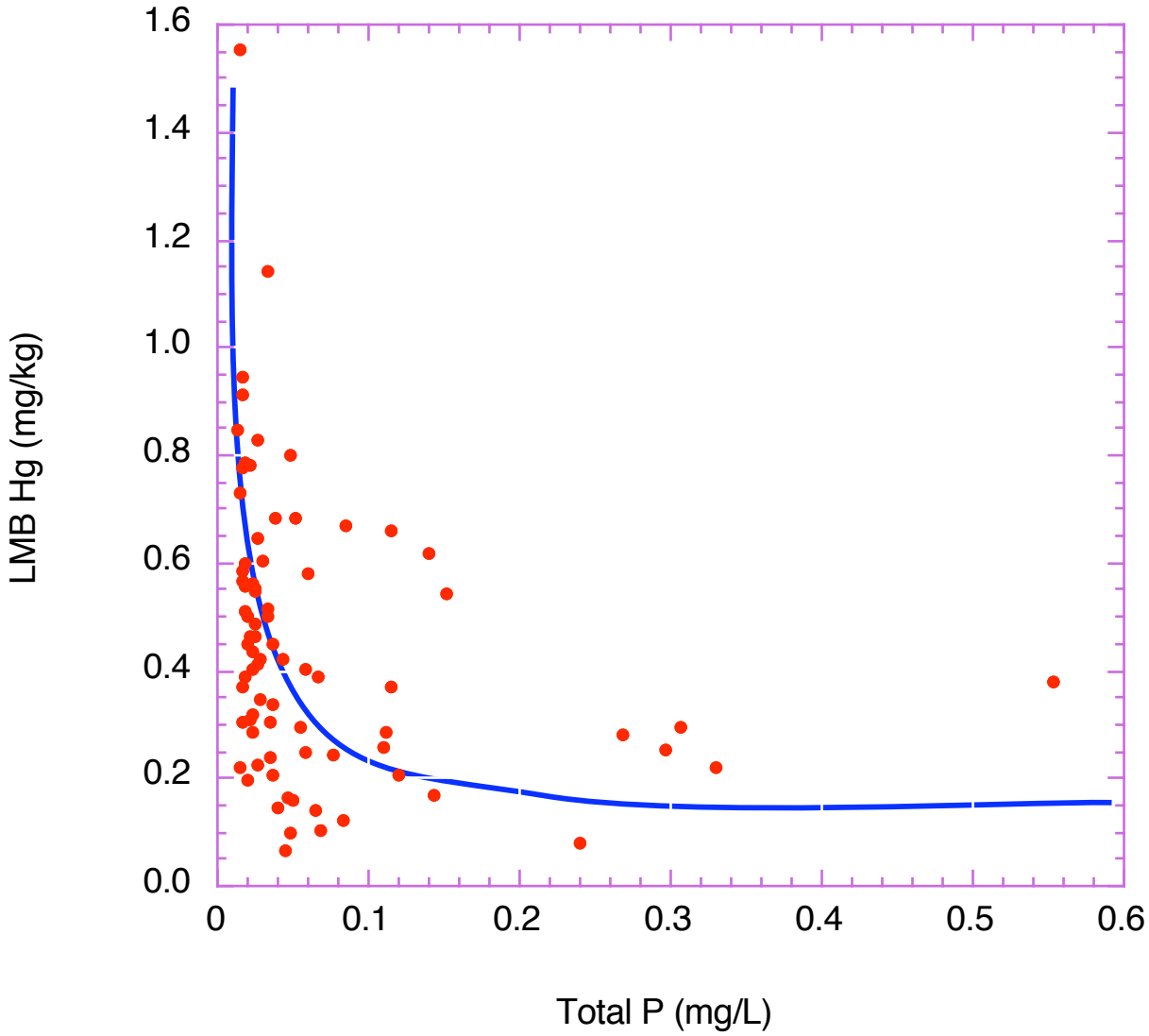
- **Primary Assumption** - Mercury concentrations in fish are linearly related to mercury loadings.
  - Assumption is supported by dose response studies conducted in the Florida Everglades and Canada
- **Second Assumption** - Fish tissue concentrations *across* lakes and streams are dominated by biogeochemical variables other than mercury loading, while variations in fish tissue concentrations *within* a lake (all other factors held constant) are governed by changes in mercury loading

Plot of Total Hg in the Water Column *vs.* Largemouth Bass (LMB) Hg

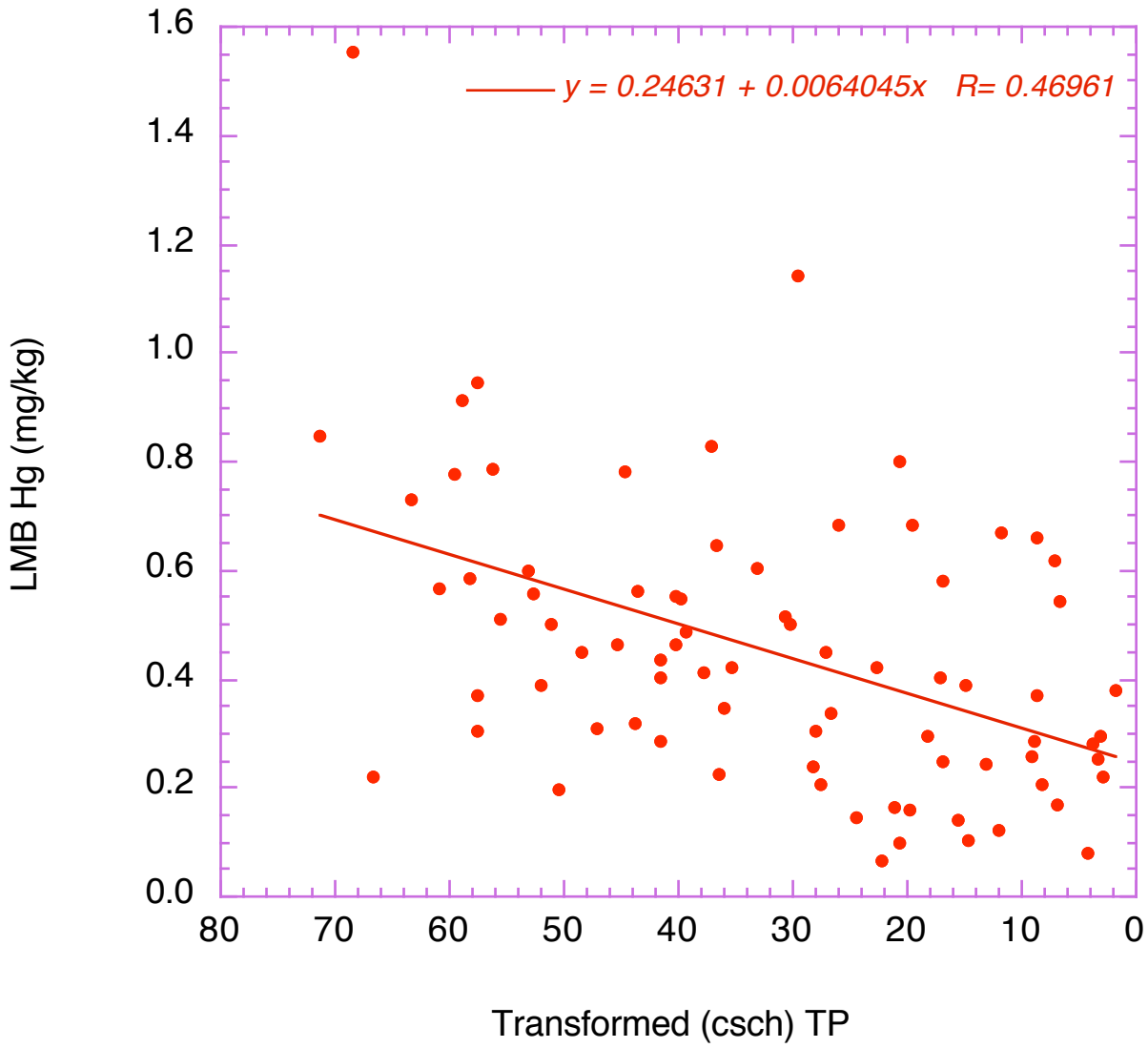
Data from Lange, Axelrad, and Pollman (unpublished), *n* = 79



Plot of Total Phosphorus in the Water Column *vs*. LMB Hg



Transformed Total Phosphorus *vs*. LMB Hg



Hypothetical Hg Deposition - TP Fish Hg Model

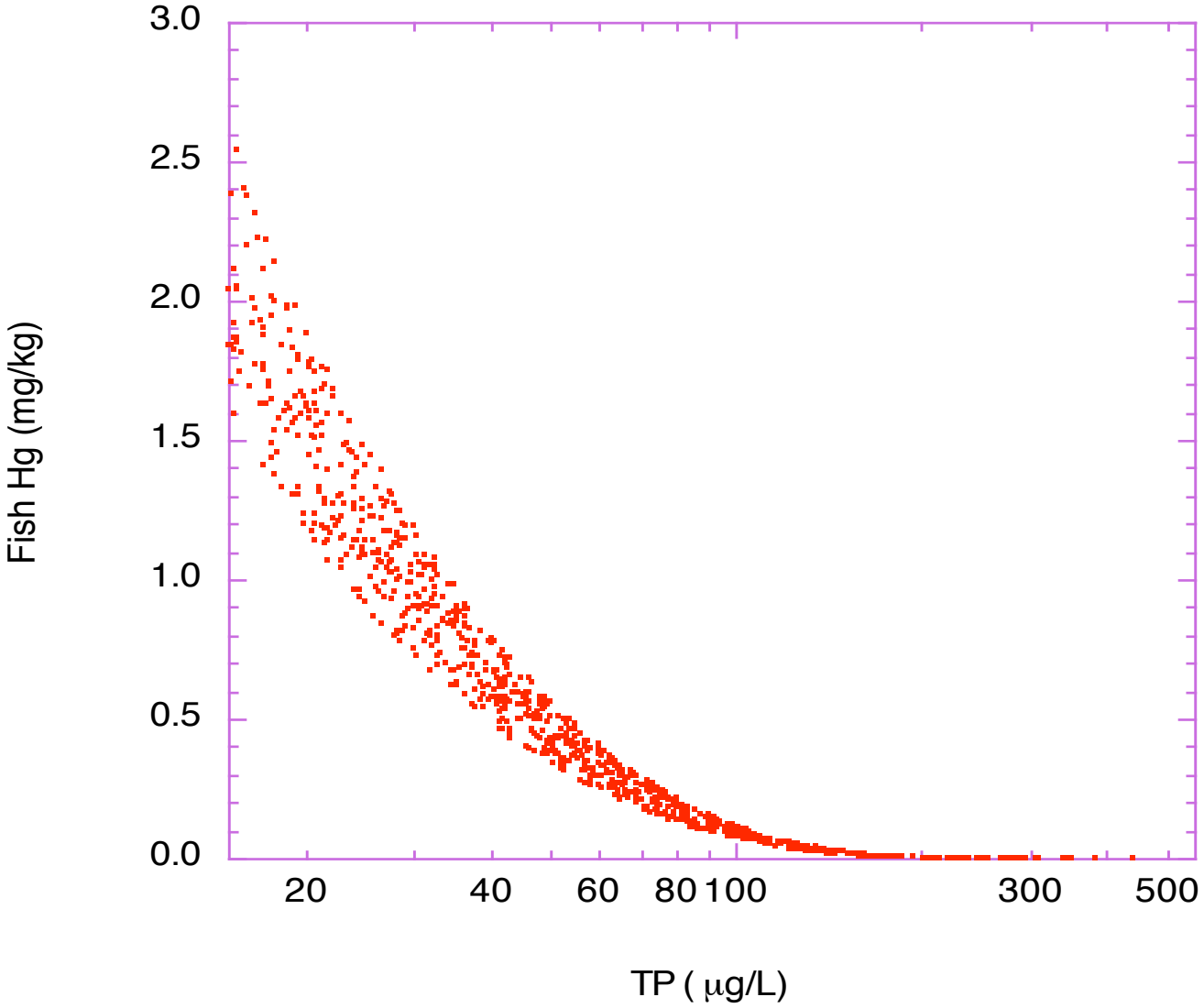
LMB Hg = $f(TP_{trans}, Hg_{atm\ dep})$

where $TP_{trans} = 1/(e^{TP} - e^{-TP})$, and

changes in LMB Hg are linearly proportional to $Hg_{atm\ dep}$

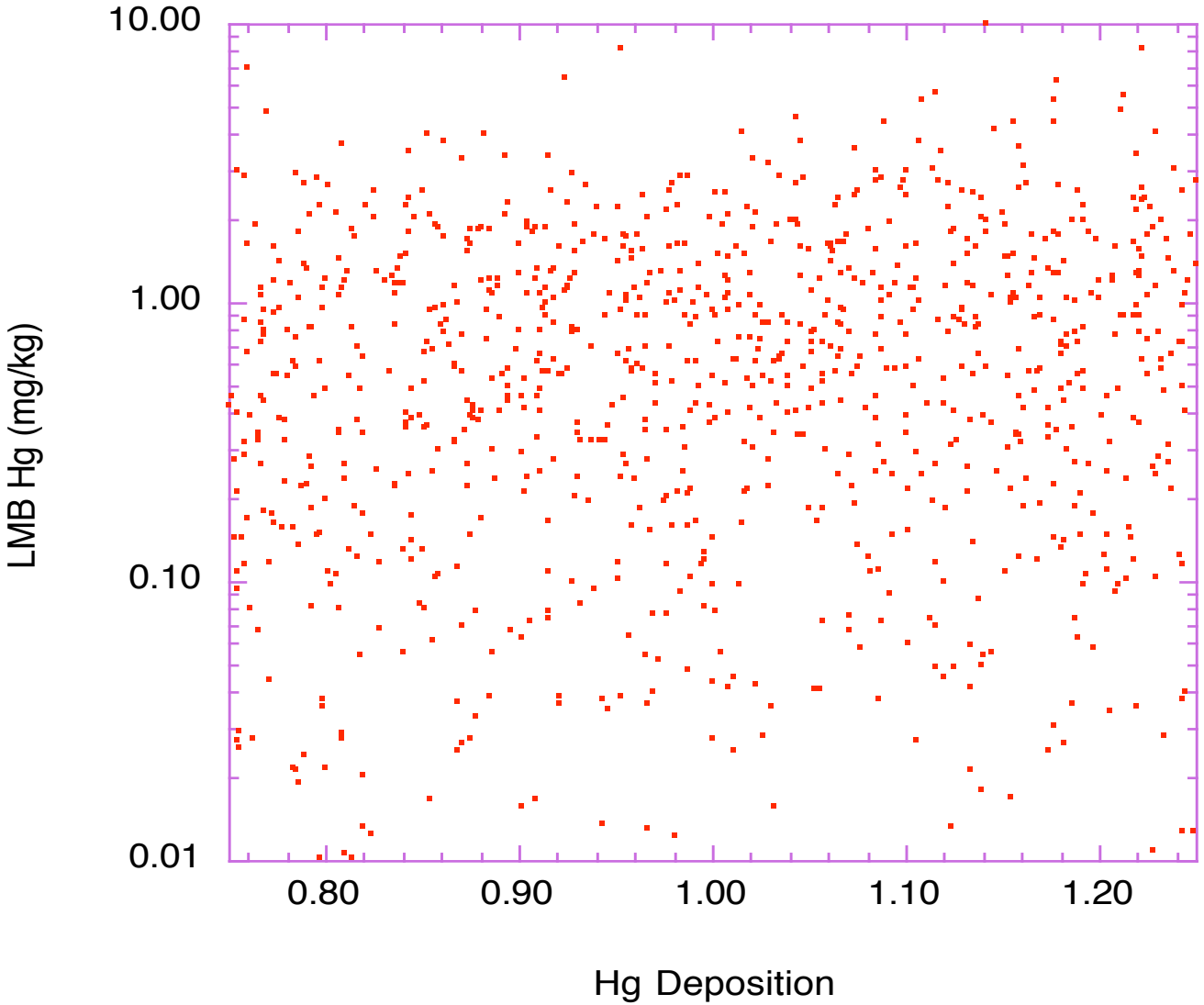
Hypothetical Hg Deposition - TP Fish Hg Model

LMB Hg *vs.* TP

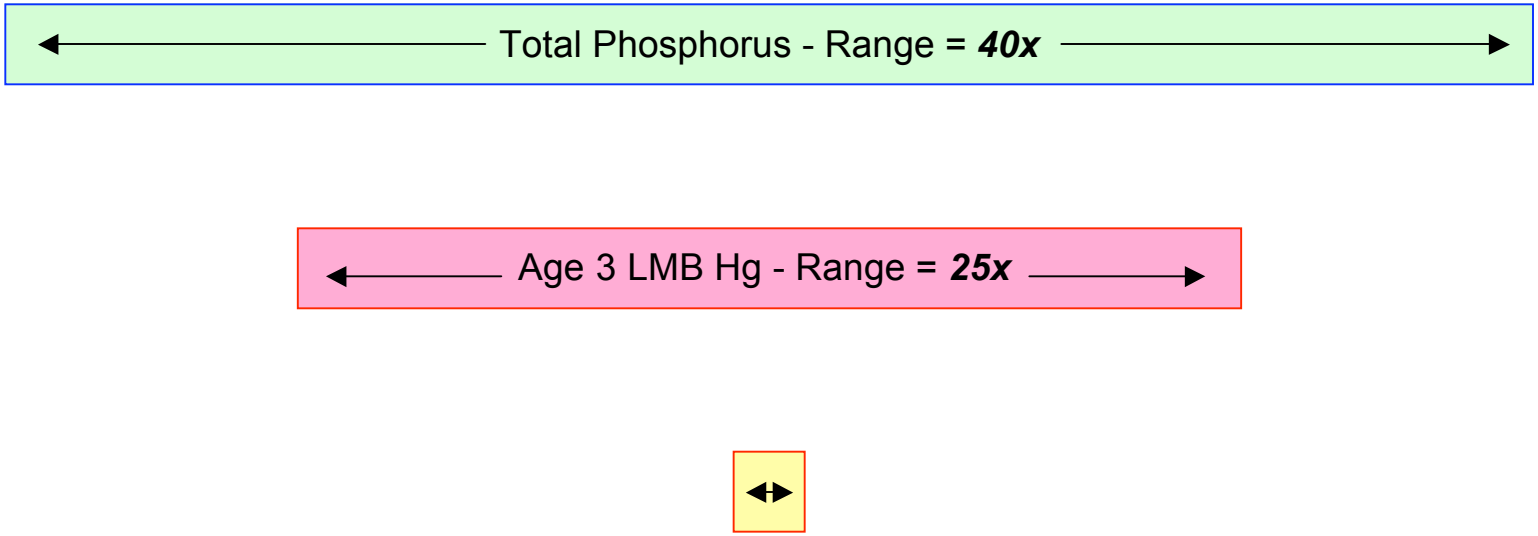


Hypothetical Hg Deposition - TP Fish Hg Model

LMB Hg *vs.* $Hg_{atm\ dep}$

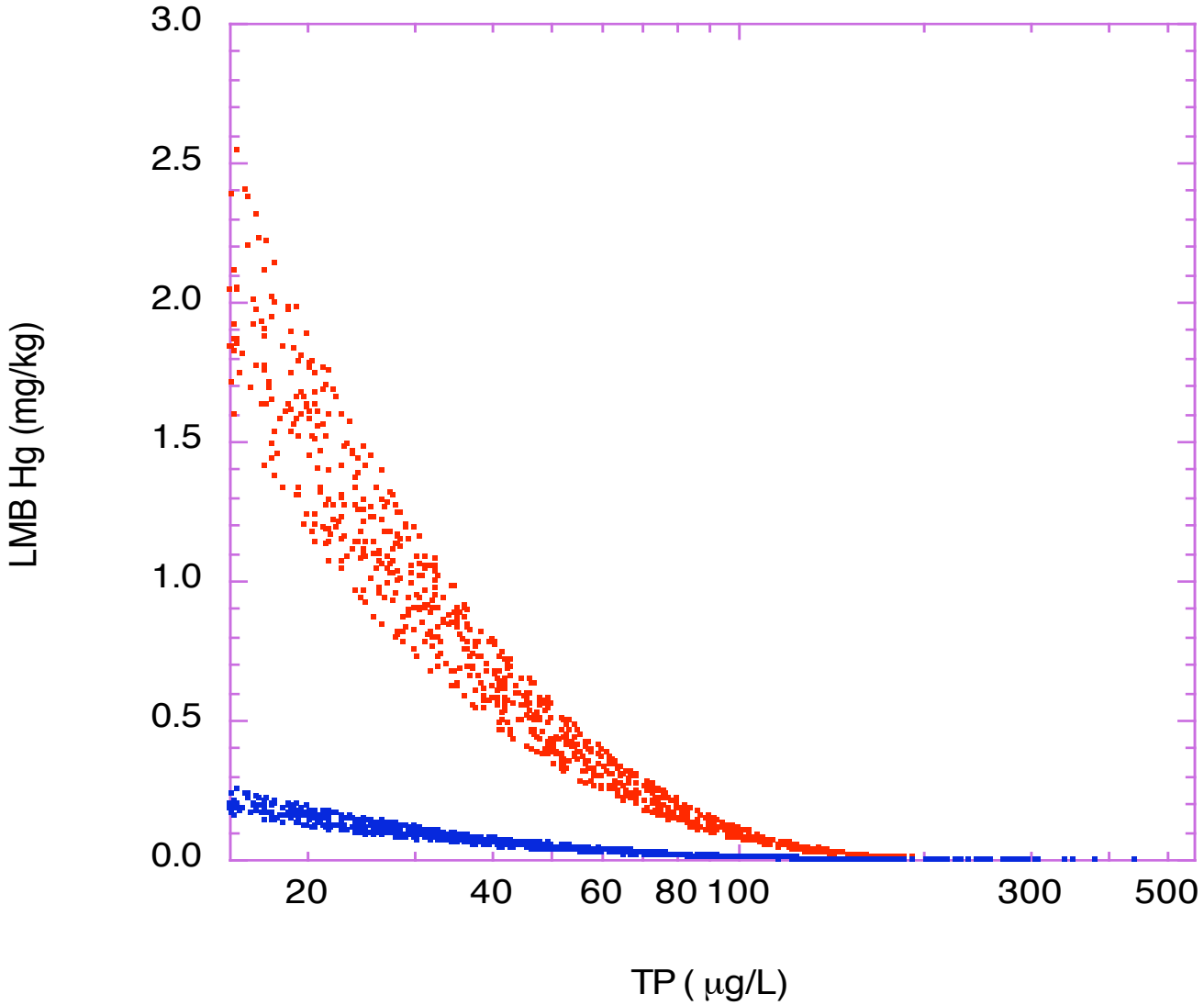


Why is mercury loading such a poor predictor *across* lakes?

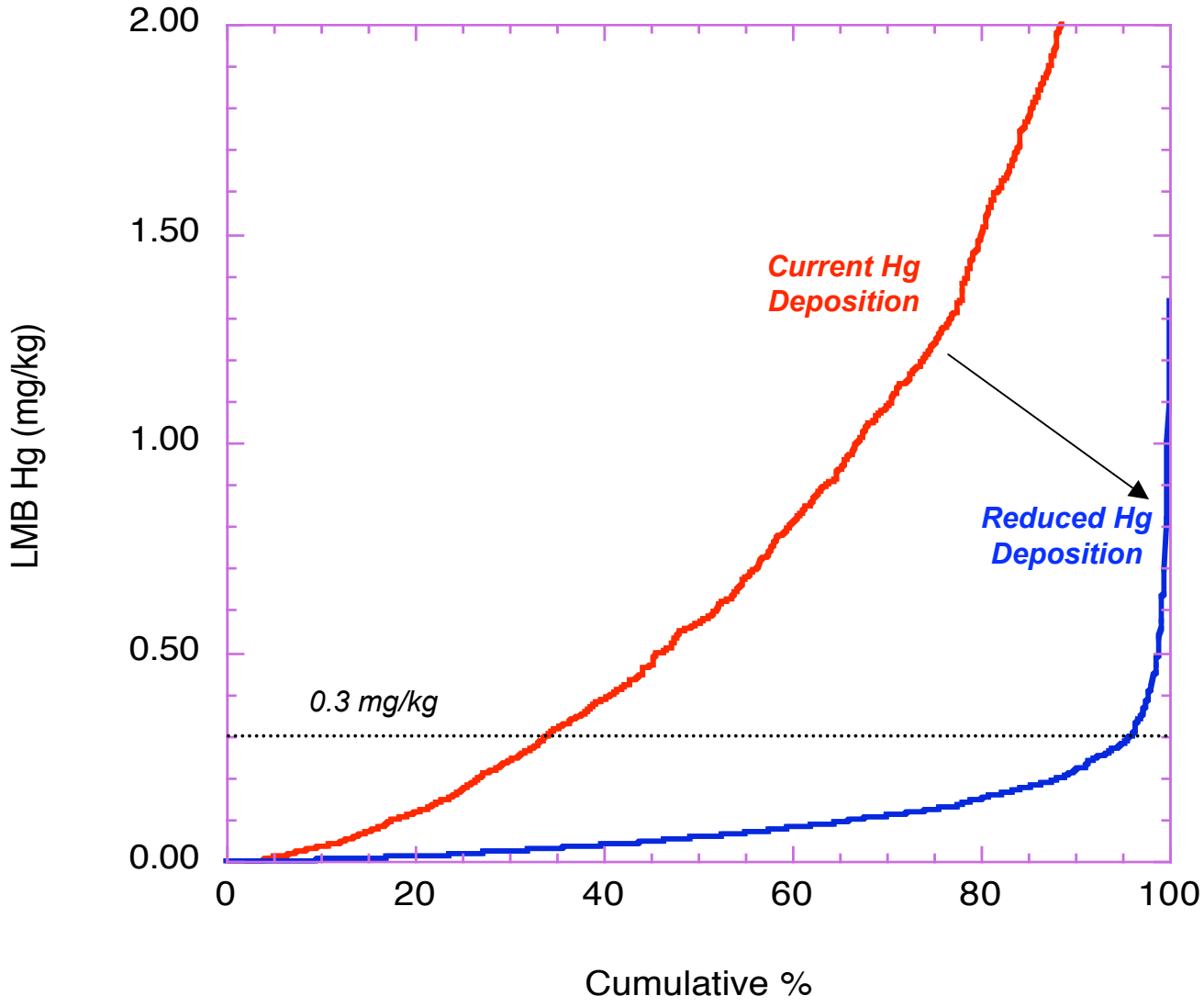


Lake data from Lange, Axelrad, and Pollman (unpublished data); Hg wet deposition from FAMS network, 1993 - 1996 (Guentzel *et al.,* 2001).

Effect of 90% Reduction in Hg Deposition on LMB Hg Concentrations in Hypothetical Deposition - TP Fish Hg Model



Effect of 90% Reduction in Hg Deposition on LMB Hg Concentrations in Hypothetical Deposition - TP Fish Hg Model



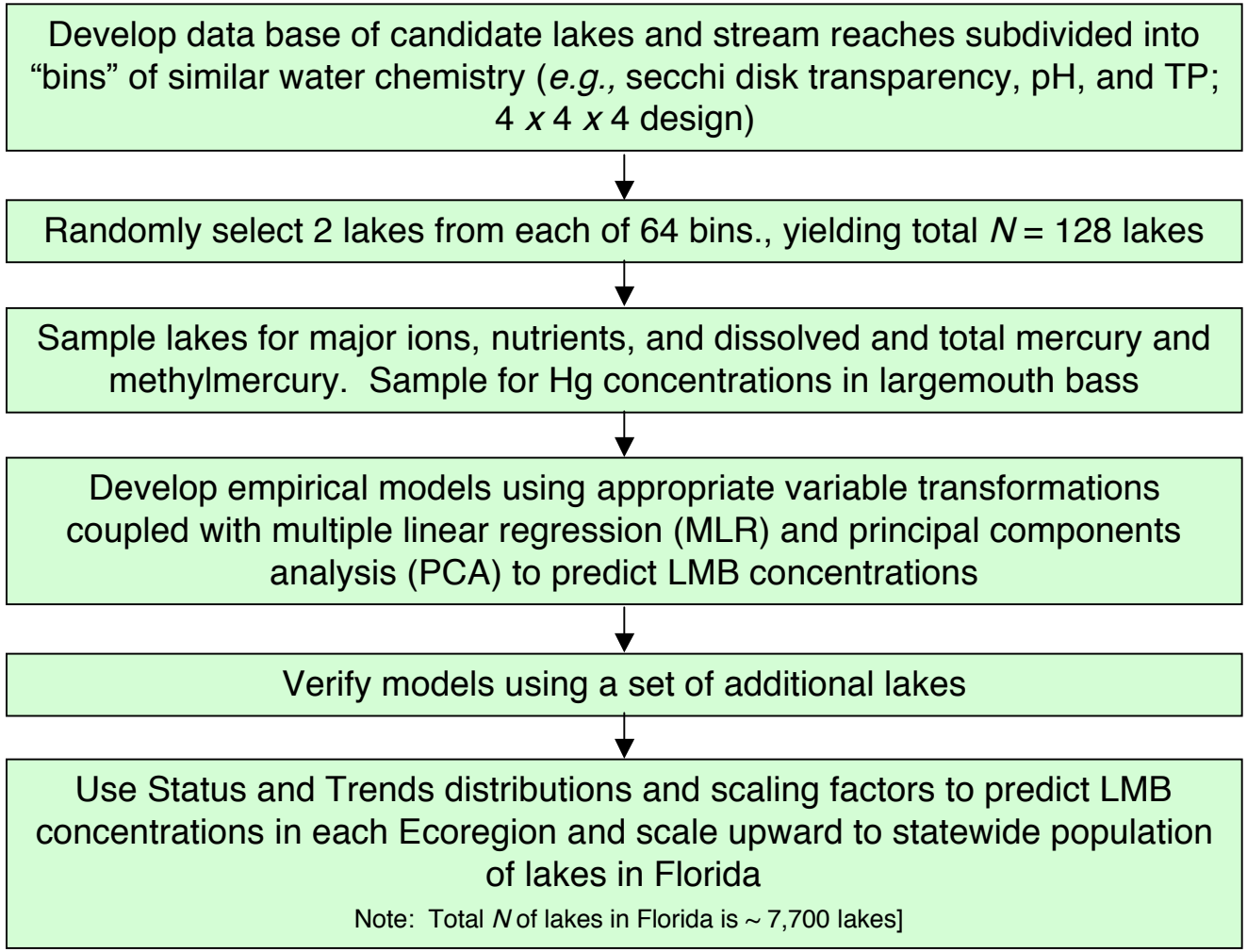
In order to predict the distribution of mercury in fish across lakes and streams in Florida in response to changes in mercury loadings, we need three things:

1. We need to be able to robustly characterize the relationship between other water quality variables and fish Hg concentrations across lakes and streams.

2. We need to be able to map how changes in mercury emissions will translate to changes in atmospheric loading of mercury to individual lakes and stream reaches across the state.

3. We need to be able to scale the aquatic empirical modeling results up to a regional and statewide level.

Empirical Model to Predict Largemouth Bass Hg Concentrations in Florida Lakes and Streams



Example Empirical Model Results

From Lange et al. (unpublished data)

PCA Model

LMB Hg = -0.971 + 0.233·*Factor2* - 0.302·*Factor3* +0.318·*Factor4*

$R^2 = 0.629$

MLR Model

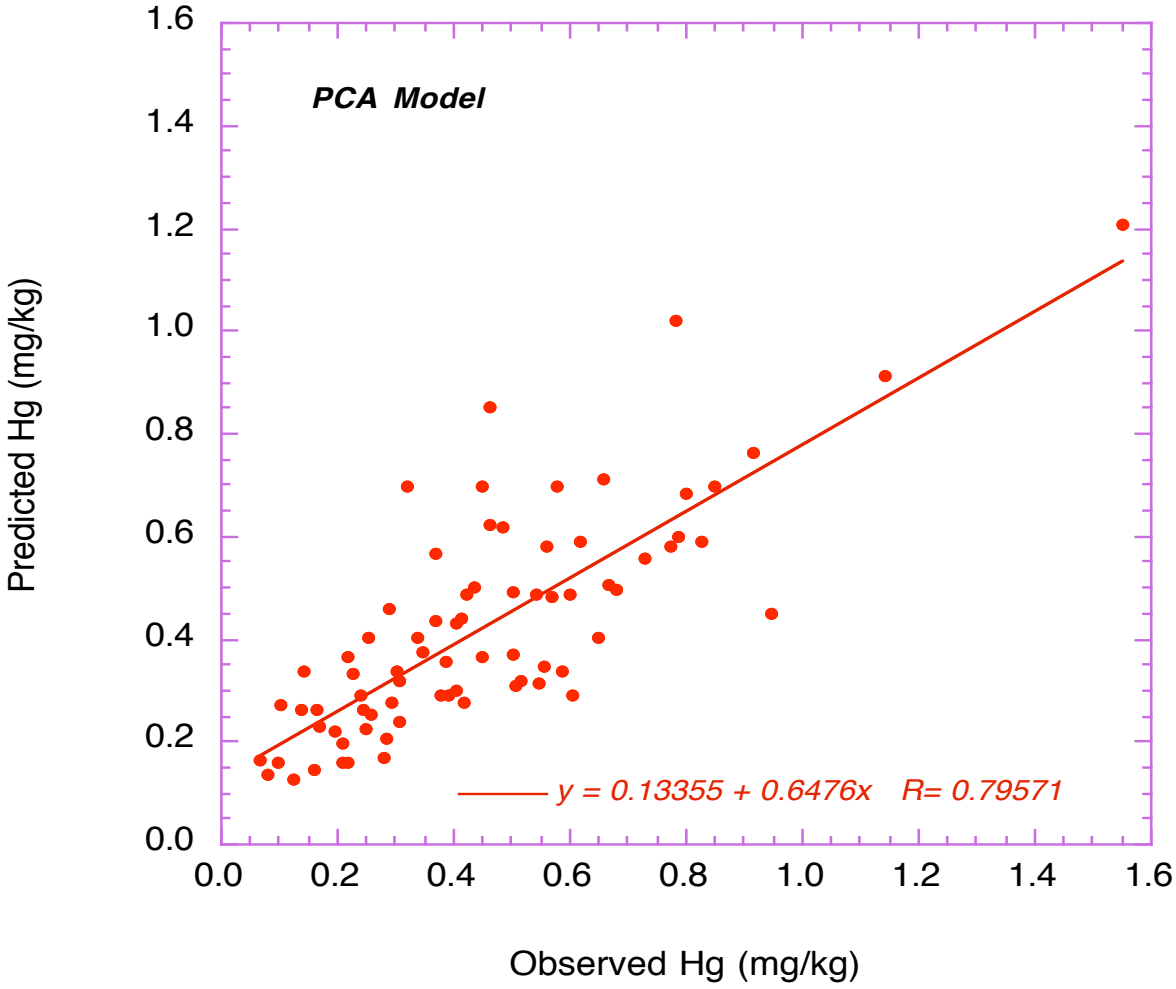
LMB Hg = 1.134 - 0.241·pH - 0.203·*Ln Chla* + 0.140·*Ln* $MeHg_{Unfiltered}$ + 0.262·*Ln* $Hg_{Total\ unfiltered}$

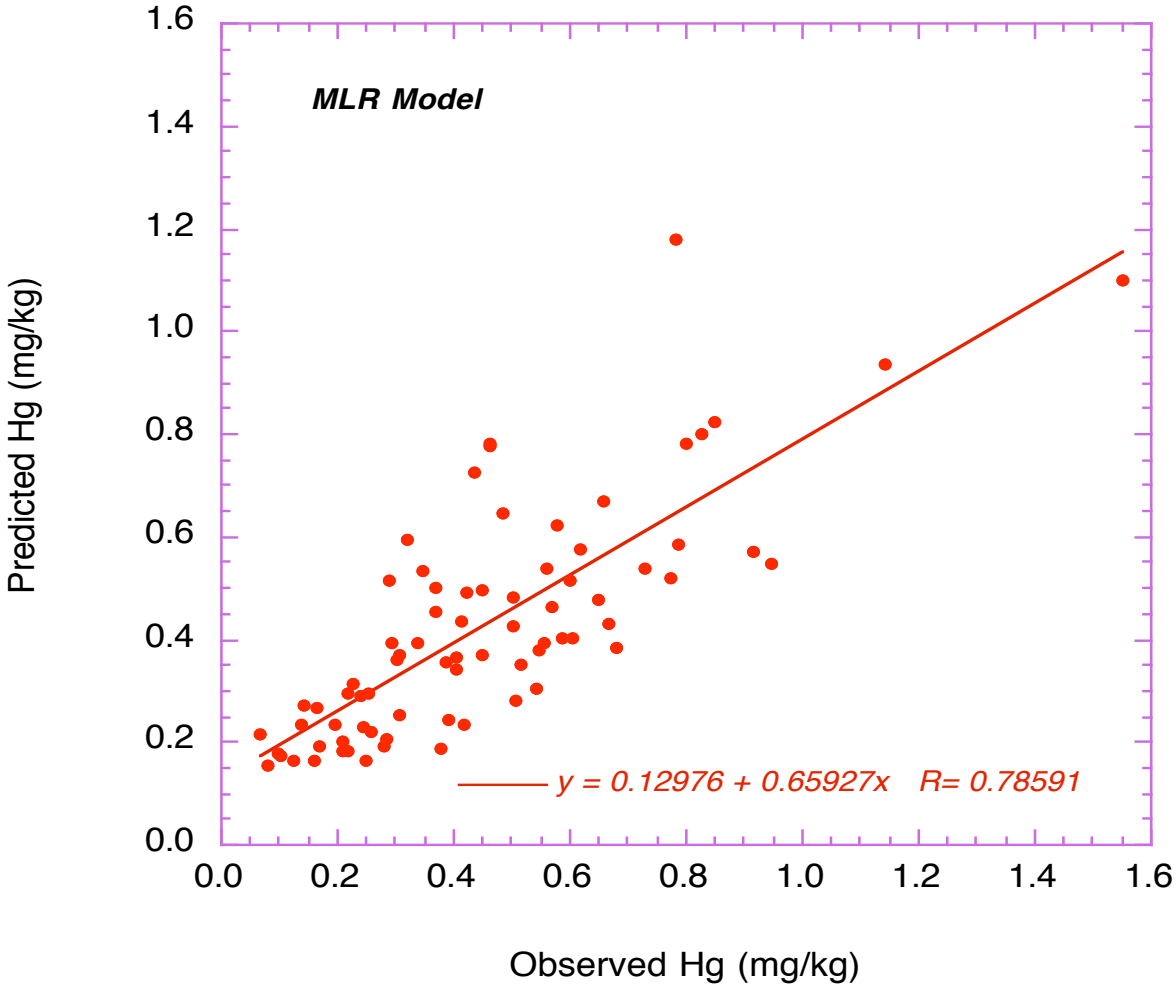
$R^2 = 0.688$

Eastern Lakes Survey (ELS) Variable Model

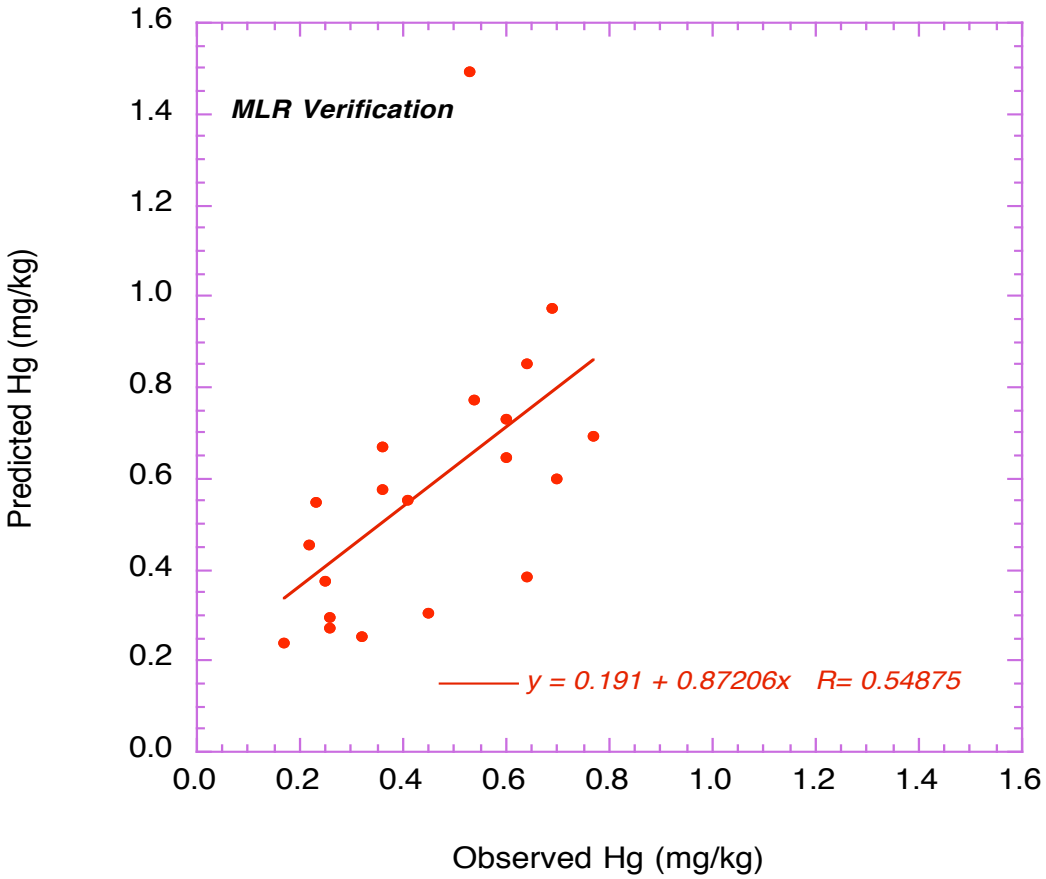
LMB Hg = 0.411 - 0.498·pH + 0.311·*Ln DOC* + 0.280·*Ln Secchi* + 0.119·*Ln DOC*

$R^2 = 0.558$

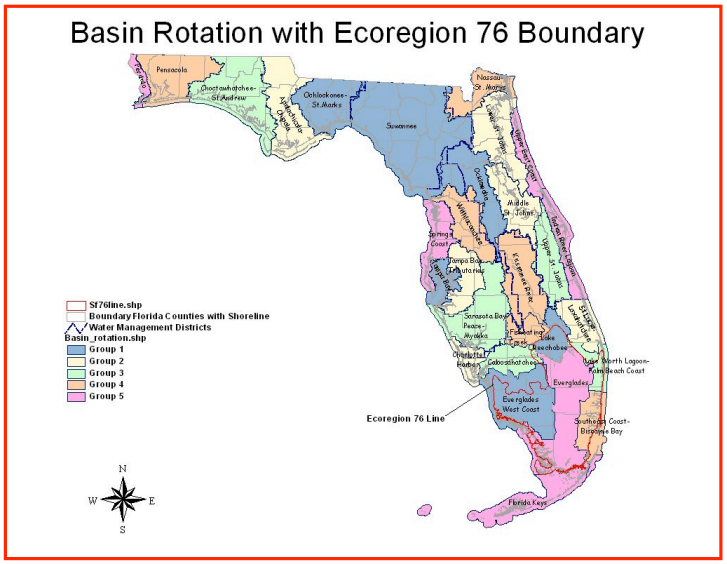

PCA Model
y = 0.13355 + 0.6476x R= 0.79571
Predicted Hg (mg/kg)
Observed Hg (mg/kg)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6


MLR Model
y = 0.12976 + 0.65927x R= 0.78591
Predicted Hg (mg/kg)
Observed Hg (mg/kg)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

MLR Model Verification



Scaling Modeling Results to Statewide Level



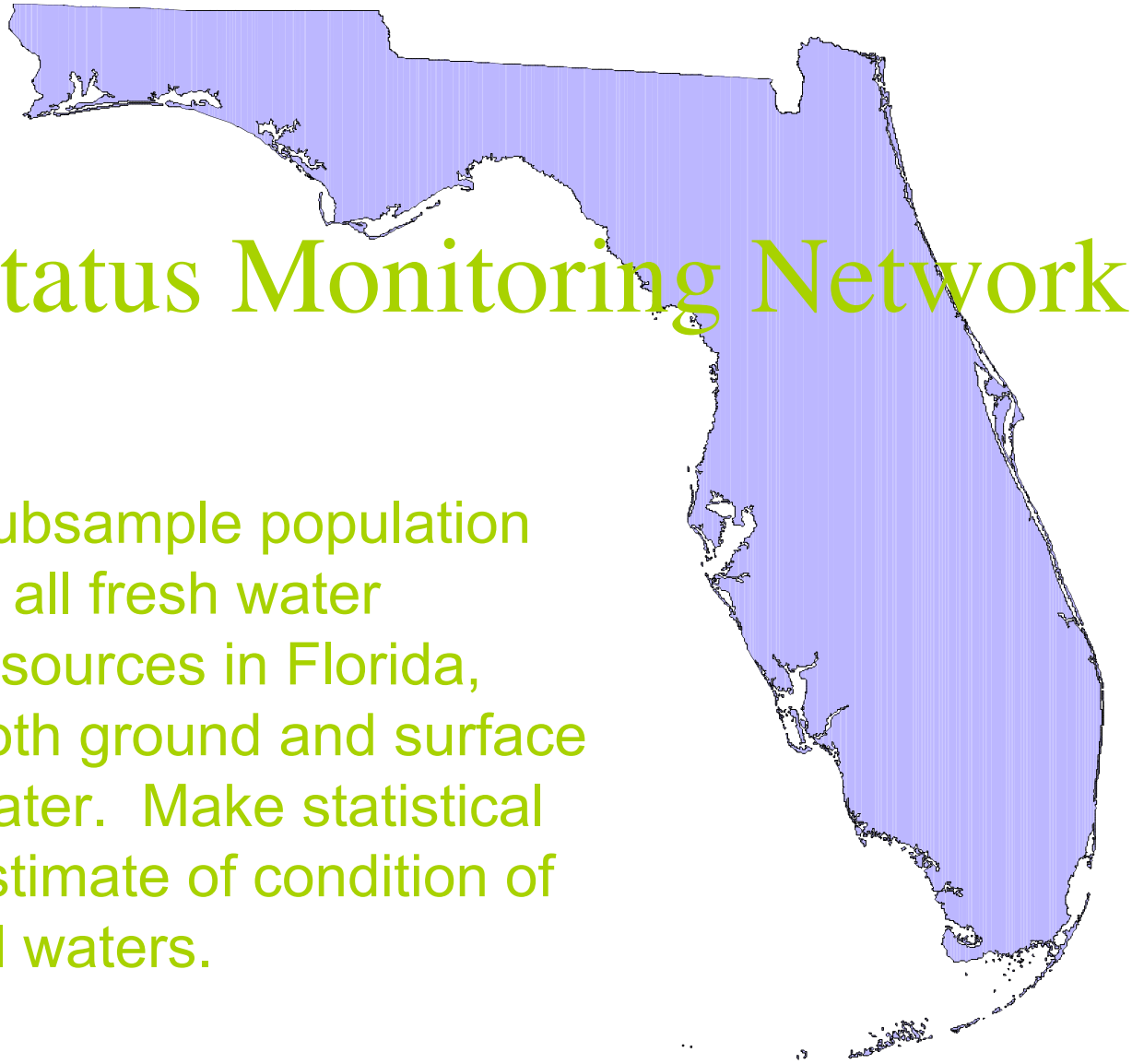
1. Randomly sample within a given physiographic region or HUC (stratified random sampling)

2. Based on total number of lakes, *N,* within region and number of lakes sampled, *n,* develop regional scaling factor. Depending on objectives, *N* may be reduced based on appropriate exclusion criteria.

3. Apply empirical model to sample lakes to determine cumulative frequency distribution of model endpoint (*e.g.,* LMB Hg) within given region.

4. Scale results upward for each physiographic region. Combine results for all regions, and determine overall *cfd* for model endpoint across the state.

Status Monitoring Network

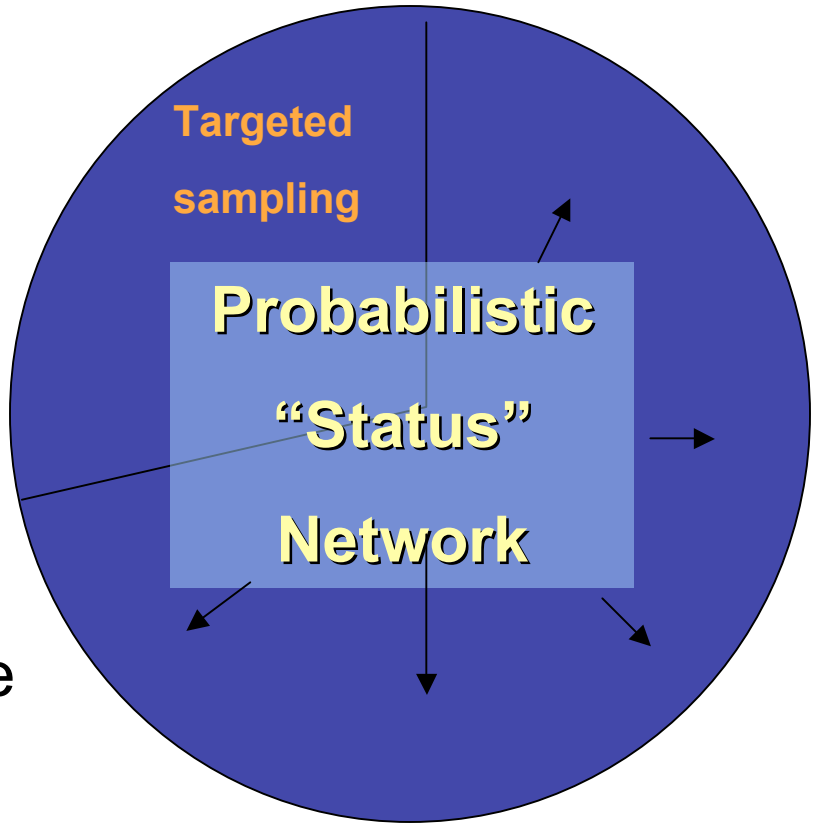


Subsample population of all fresh water resources in Florida, both ground and surface water. Make statistical estimate of condition of all waters.

What is the function of a Statewide Status Network?

With Targeted Sampling few waters may be reported each year in 303(d) and 305(b) reports.

What is the condition of the rest?



Probabilistic Monitoring (statistical random sample design)

Gives estimate of condition for 100% of the sampleable Statewide Water Resources

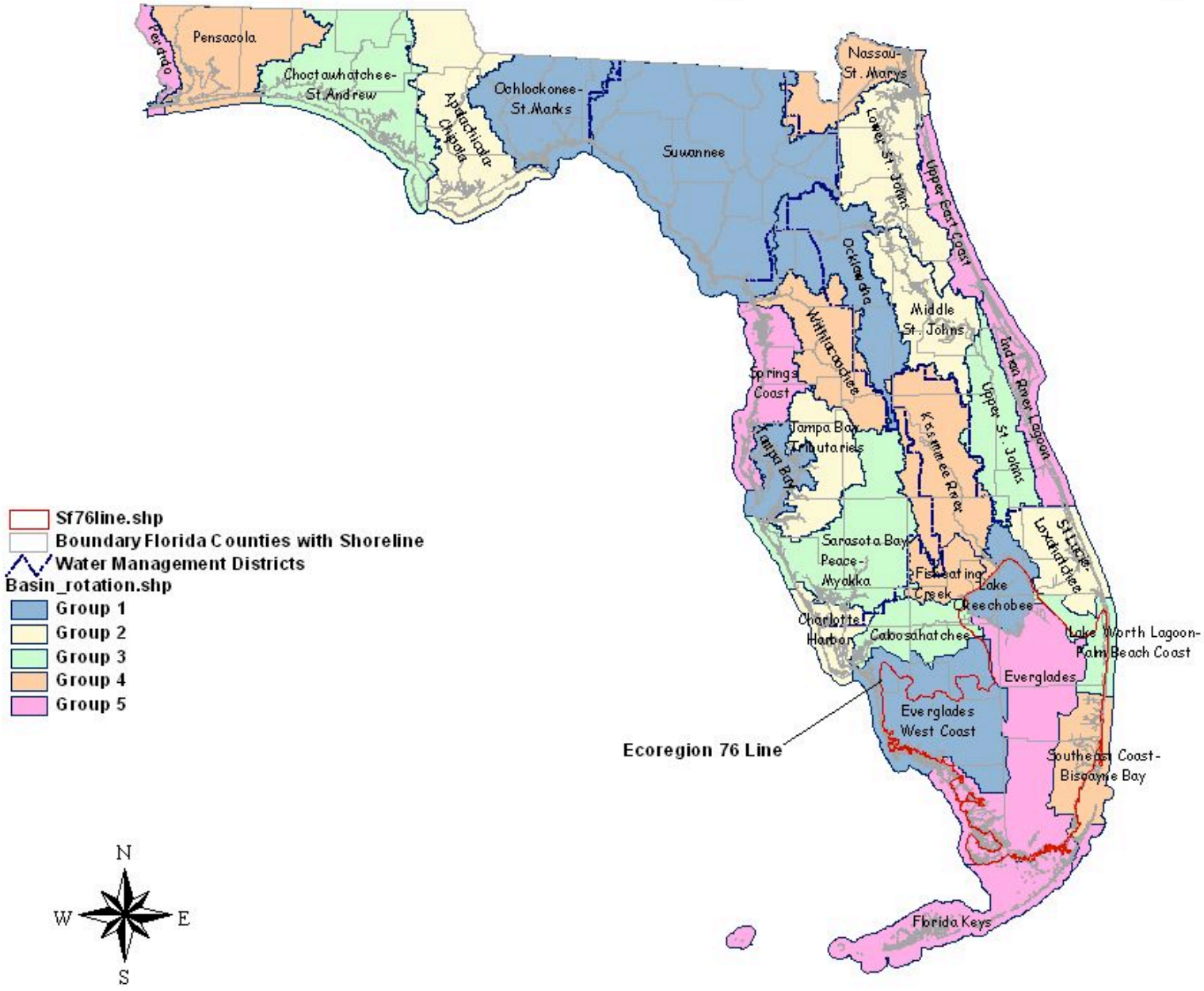
STATUS MONITORING NETWORK

Design:

1) Characterize regional to statewide water resource conditions, using a 5 year rotating basin, multi-year probabilistic sampling approach;

2) Determine percentage of each resource within each basin which meets standards or designated use (surface & ground water).

Basin Rotation with Ecoregion 76 Boundary



Freshwater Resource Types

- Streams
- Rivers & Canals
- Small Lakes (1-9.9 hectares)
- Large Lakes (> 10 hectares)
- Unconfined Aquifers
- Confined Aquifers

Surface Water Population

Limit population to systems where Water Quality Standards apply (Waters of the State)

Rivers and Streams

Named waterbody or connected to other waters of the state

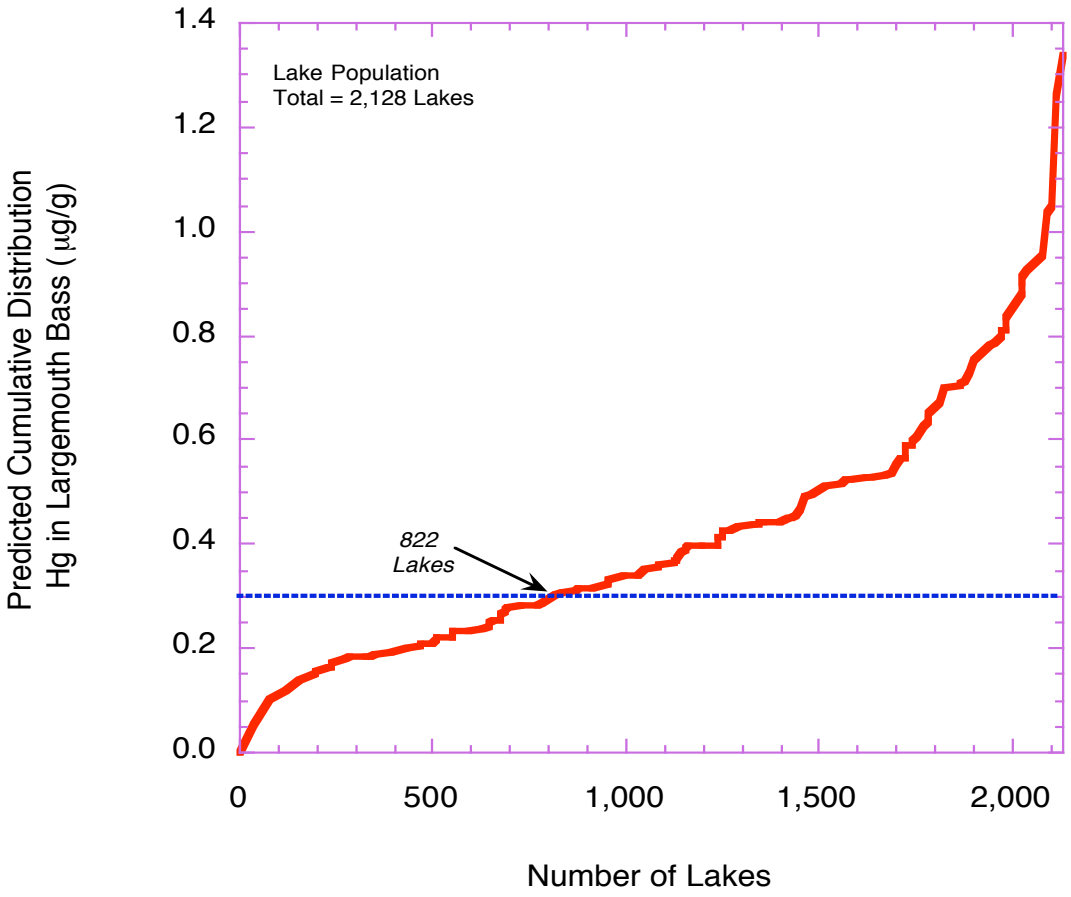
Small lakes (1-9.9 hectares).

Does not include lakes that are not considered waters of the state. (stormwater ponds, borrow pits, ag ponds).

Large lakes (> 10 hectares).

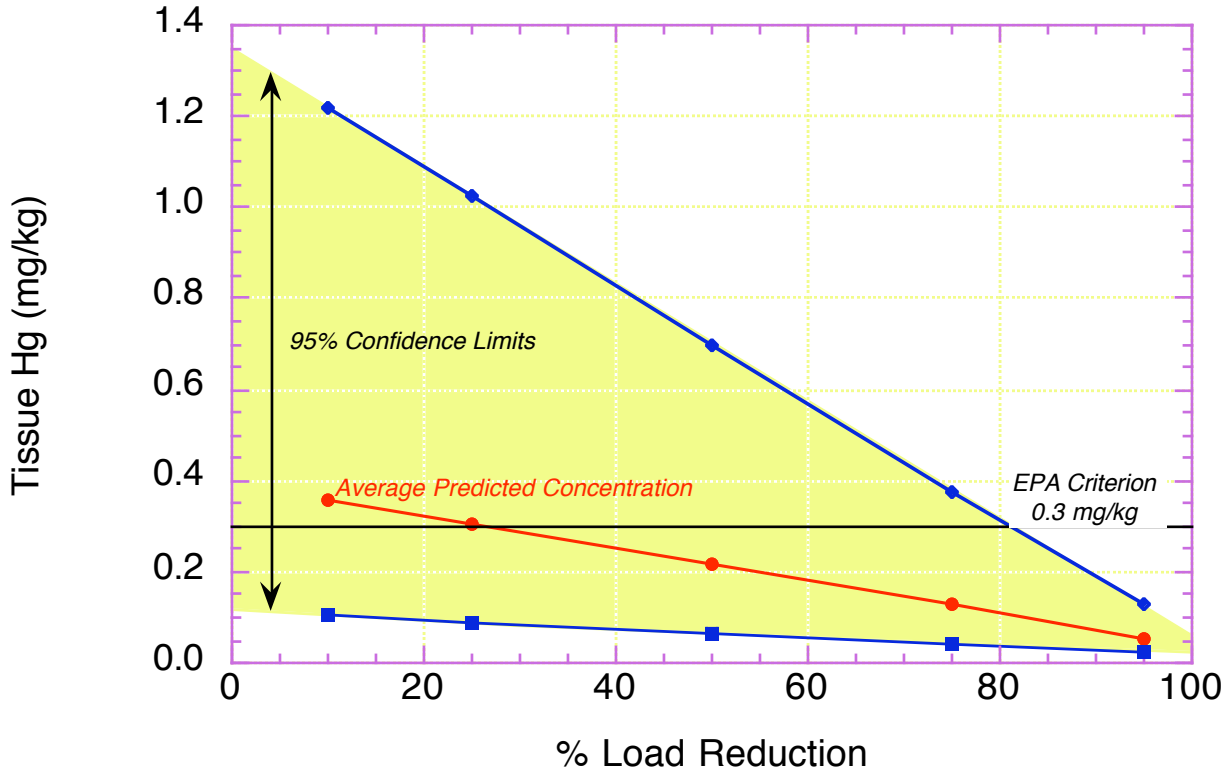
Natural lakes and large impoundments.

Predicted Cumulative Distribution of Mercury Concentrations in Largemouth Bass in Florida Lakes



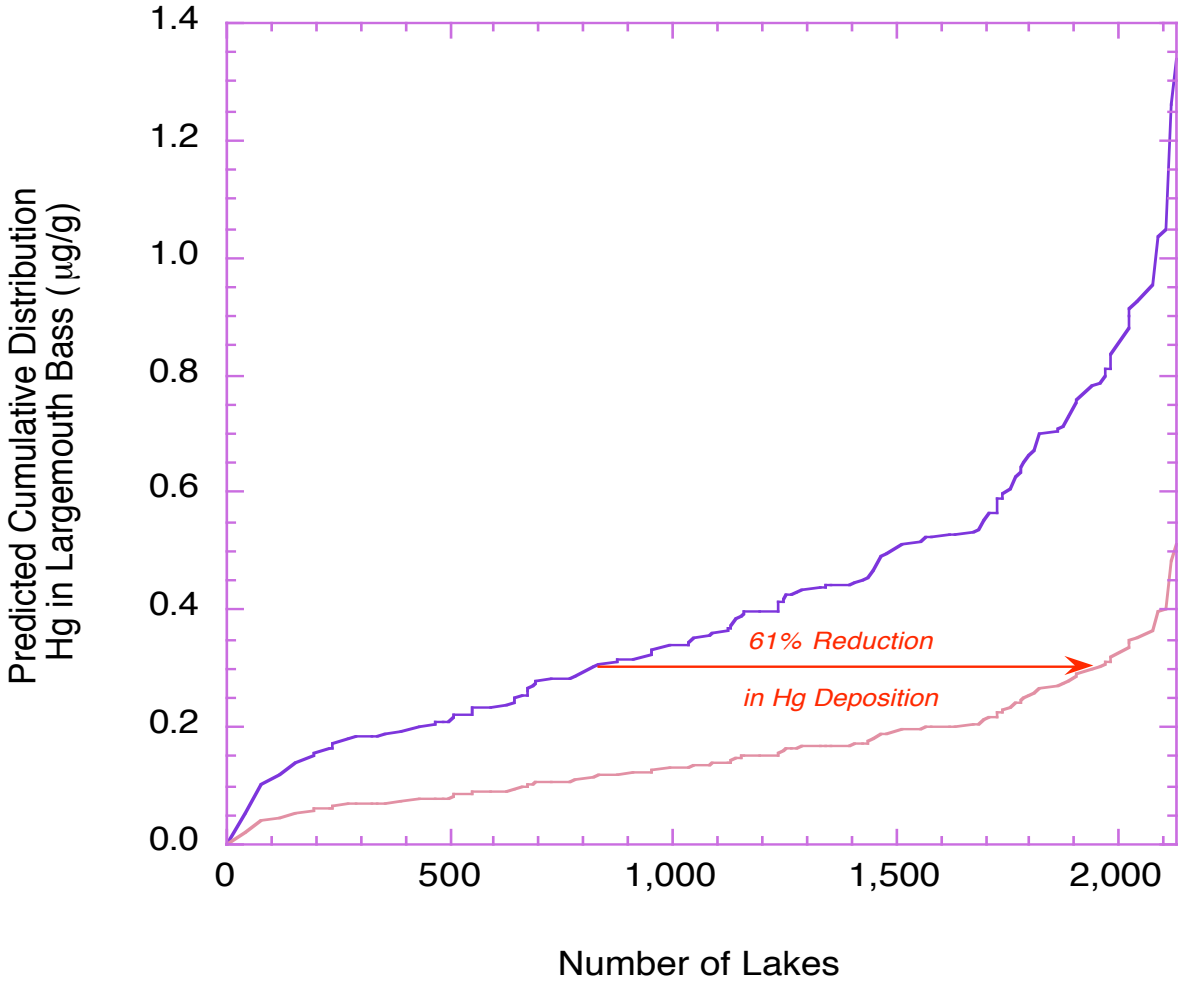
Margin of Safety

Example Margin of Safety Analysis Conducted for Devils Lake, WI Pilot Hg TMDL. Steady state conditions.

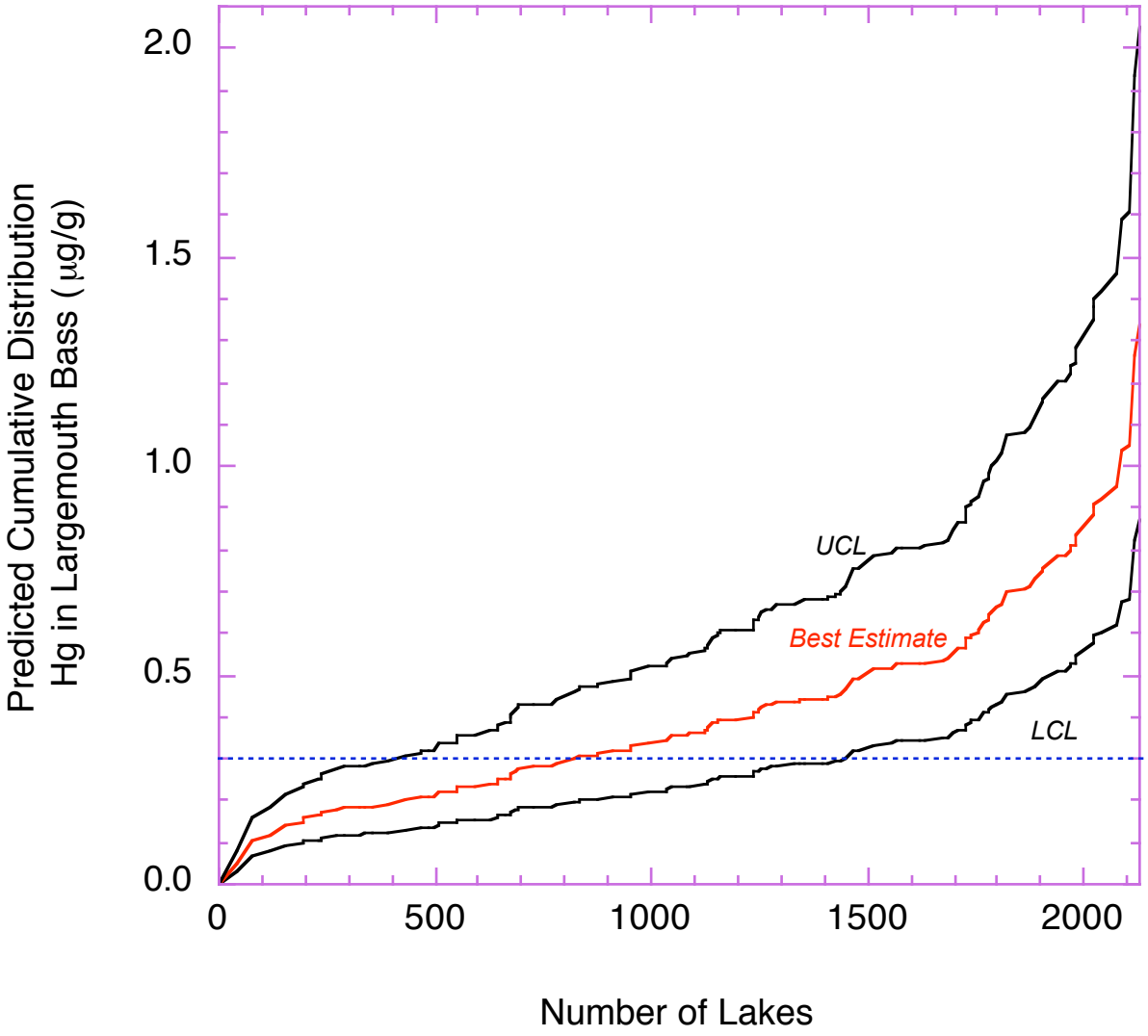


From Pollman et al. (2007).

Margin of Safety (90% *cfd*) Applied to Empirical Model Prediction of Mercury Concentrations in Largemouth Bass in Florida Lakes



Predicted Cumulative Distribution of Mercury Concentrations in Largemouth Bass in Florida Lakes



Schedule for Aquatic Modeling and TMDL Report

TMDL Work Element	2007				2008				2009				2010				2011				2012			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
			FY 2007-2008				FY 2008-2009				FY 2009-2010				FY 2010-2011				FY 2011-2012					
Project Initiation - Initial WQ-Fish Hg Data Assessment																								
1 Present project overview to stakeholders			o-x																					
2 Obtain and Analyze FDEP Status and Trends Data (including scaling algorithm)			o--	--x																				
3 Obtain and analyze FDEP fish Hg data (including scaling algorithm)			o--	--x																				
4 Obtain and analyze Everglades WQ data			o--	-----	-----	--x																		
5 Develop list of lakes and stream reaches for fish sampling related to development of empirical model.				o-x																				

TMDL Work Element	2007				2008				2009				2010				2011				2012			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
			FY 2007-2008				FY 2008-2009				FY 2009-2010				FY 2010-2011				FY 2011-2012					
Develop Regional Aquatic Hg Model																								
1 Collect water chemistry and fish data (FDEP).					o--	-----	-----	-----	-----	-----	-----	-----	-----	--x										
2 Analyze data and develop empirical models							o--	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	--x						
3 Compile Status and Trends lakewater data								o-x						o--	--x									
4 Compile Status and Trends streamwater data								o-x						o--	--x									
5 Compile Everglades WQ data								o-x						o--	--x									
6 Format and reduce WQ data and integrate with fish Hg data														o-x										
7 Develop weighting algorithm for Everglades data								o-x						o-x										
8 Develop preliminary models									o-x															
9 Develop final models															o-	-x								
10 Verify final models																o-x								

TMDL Work Element	2007				2008				2009				2010				2011				2012			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
			FY 2007-2008				FY 2008-2009				FY 2009-2010				FY 2010-2011				FY 2011-2012					
Conduct Regional TMDL Analysis																								
1 Develop target endpoint (FDEP)					o--	-----	-----	--x																
2 Conduct regional and statewide modeling of Hg distributions															o--	--x								
3 Determine regional and statewide reductions in Hg loads															o--	--x								
4 Determine margin of safety appropriate to endpoint and apply to load reductions																o-x								
5 Determine local and larger scale source reductions																	o--	--x						
6 Develop Draft (stand-alone) Aquatic Modeling Report																	o--	--x						
6 Develop Draft Sections for TMDL Report																	o--	--x						
7 FDEP Review																		o-x						
8 Revise Reports																			o-x					
9 FDEP Final Draft Review																			o-x					
10 Submit TMDL Report to Stakeholder																			o-x					
11 Stakeholder Review																				o-x				
12 Revise TMDL Report																						o-x		
13 Submit Final TMDL Report																						o-x		

Summary & Major Issues

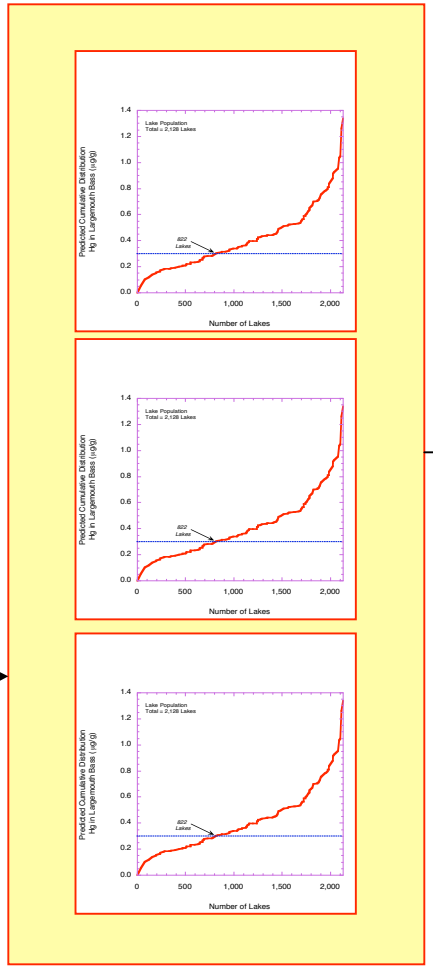
Elements of Empirical Model Regional Hg TMDL

1. Develop empirical model that predicts target endpoint (*e.g.*, LMB Hg concentrations) as a function of water chemistry.
2. Approach assumes that, although there may not be a relationship across the lakes between Hg fish tissue concentrations and Hg concentrations in the water column, fish tissue concentrations are still driven by mercury inputs and that this relationship *within a given lake* is linear.
3. Use the empirical model in conjunction with an appropriate regional data set with compatible chemical input data to scale response upwards to characterize fish Hg *cfd* within particular subregions in Florida
4. Regional data sets will be derived from FDEP Status and Trends network.
5. Delineate atmospheric and point source inputs of Hg within each ecoregion (CMAQ modeling for spatially dependent atmospheric loadings of Hg as a function of local and larger scale source inputs).
6. Determine requisite reductions in loads necessary to achieve target reductions, using uncertainty analysis to factor in Margin of Safety.
7. Allocate load reductions to source categories.

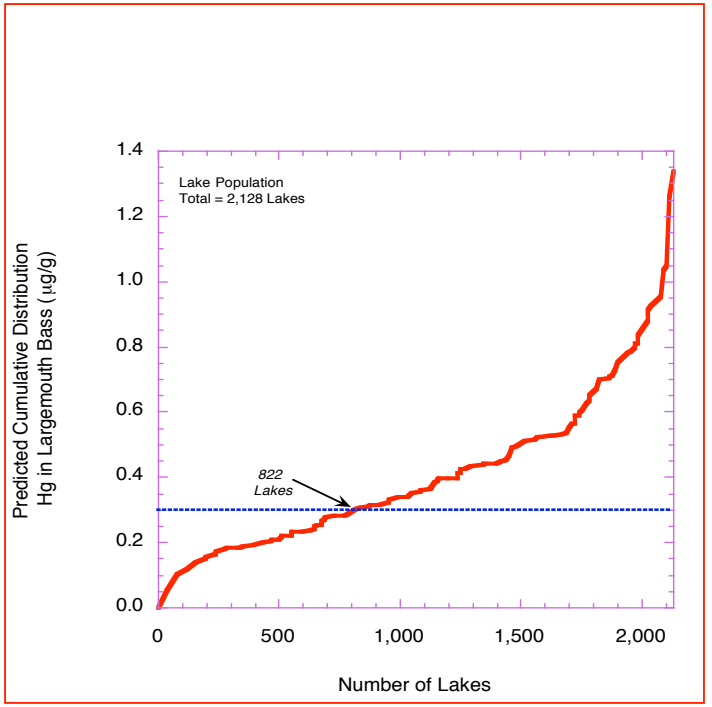
Sample lakes using balanced bins
64 bins
N = 128

Develop Empirical Model

Apply model to each eco-region using randomized, stratified sampling



Cfd's for individual eco-region



Cfd for entire State of Florida

Summary - Major Aquatic Modeling Issues for Conducting Regional Hg TMDL

Linkage between water quality endpoints and pollutants of concern.

- Number of lakes and rivers exceeding target endpoint likely will be greater that 1,300.
- Explicitly identifying all water bodies that will exceed the endpoint and conducting individual TMDL's for each will be prohibitively expensive and resource-constrained.
- Given both the logistical problems of conducting the appropriate number of individual Hg TMDL's and the fact that the primary (if not only) source of Hg is atmospheric argues for implementing a "regional TMDL."
- Policy precedent for regional modeling to assess impact of emission controls of atmospheric pollutants (sulfate and nitrate) on aquatic ecosystems established with NAPAP 1990 Assessment
- Regional TMDL precedent established with USEPA approval of Minnesota MPCA statewide Hg TMDL in March 2007.

Summary - Major Aquatic Modeling Issues for Conducting Regional Hg TMDL

Empirical Modeling

- The distribution of fish tissue concentrations across Florida lakes and streams will be governed largely by variables related to pH and primary productivity.
- Successful predictions of the distribution of mercury concentrations in lakes and streams across Florida thus will require an empirical model that strongly captures the effect of these variables on fish tissue Hg.
- Changes in atmospheric mercury loading will impact individual lake and stream reaches in a linear manner. Changes in atmospheric loading will be supplied by the atmospheric modelers.

Summary - Major Aquatic Modeling Issues for Conducting Regional Hg TMDL

Empirical Modeling (*continued*)

- Empirical modeling by necessity will predict steady-state response. This may be less of an issue given the emerging paradigm over the past several years (both through research in the Everglades and through METAALICUS in the Canadian Experimental Lakes Area) that ecosystem response is largely driven by new Hg inputs.

- The empirical model will be used to predict fish Hg distributions using lake data and scaling factors for individual eco-regions included in FDEP's Status and Trends network. The stratified randomize design inherent in the S&T network is ideal for this type of scaling calculation.