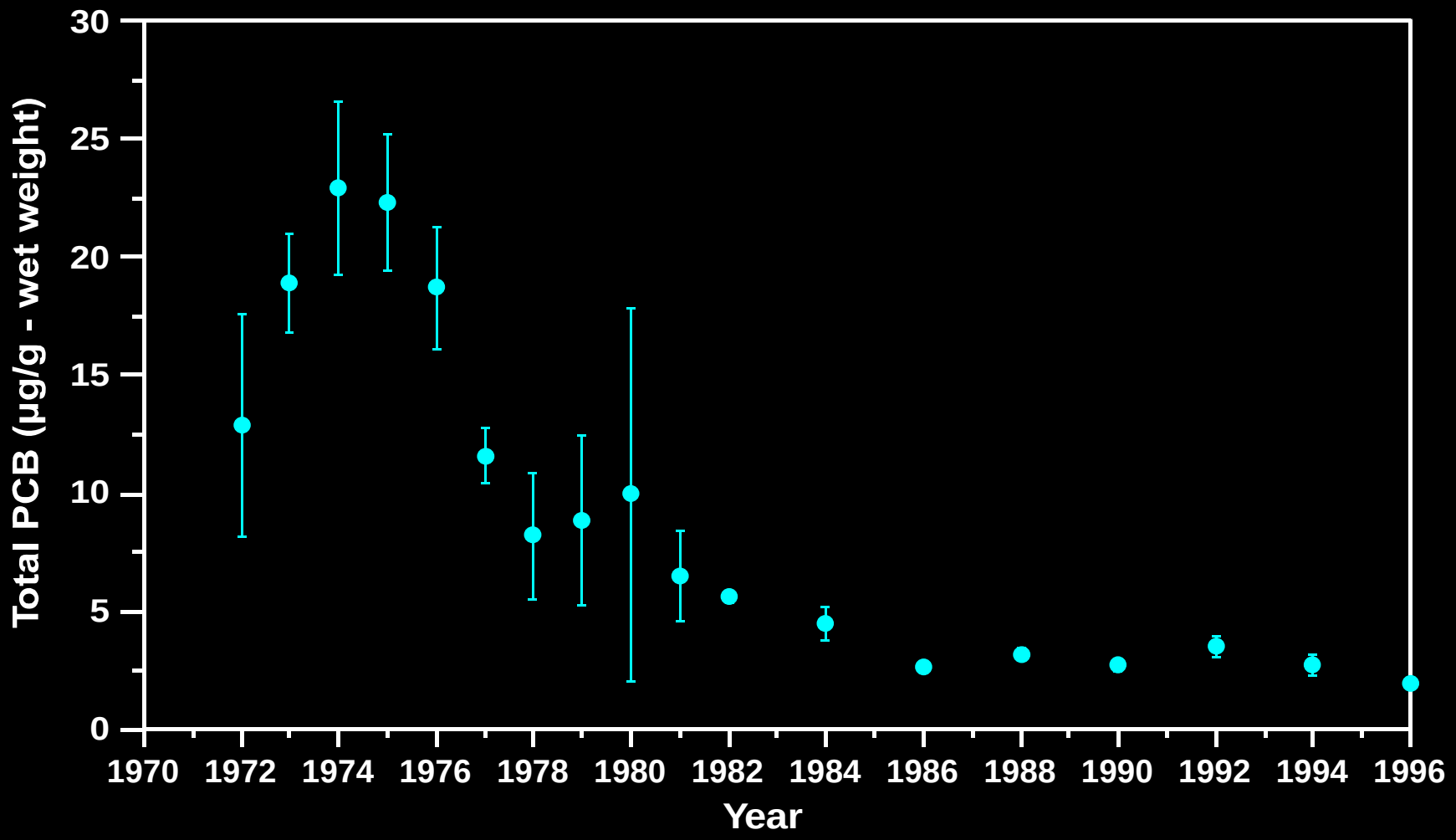
Combining prediction and monitoring for reduction of toxics: the Lake Michigan Mass Balance Study

Glenn Warren, Russell Kreis, and Paul Horvatin
U.S. EPA, Great Lakes National Program Office, 77 W. Jackson Blvd., Chicago, IL 60604,
U.S. EPA, Office of Research and Development, Large Lakes Research Station, 9311 Groh Road, Grosse Ile, MI 48138

The Problem

Total PCB Concentrations in Lake Michigan Lake Trout

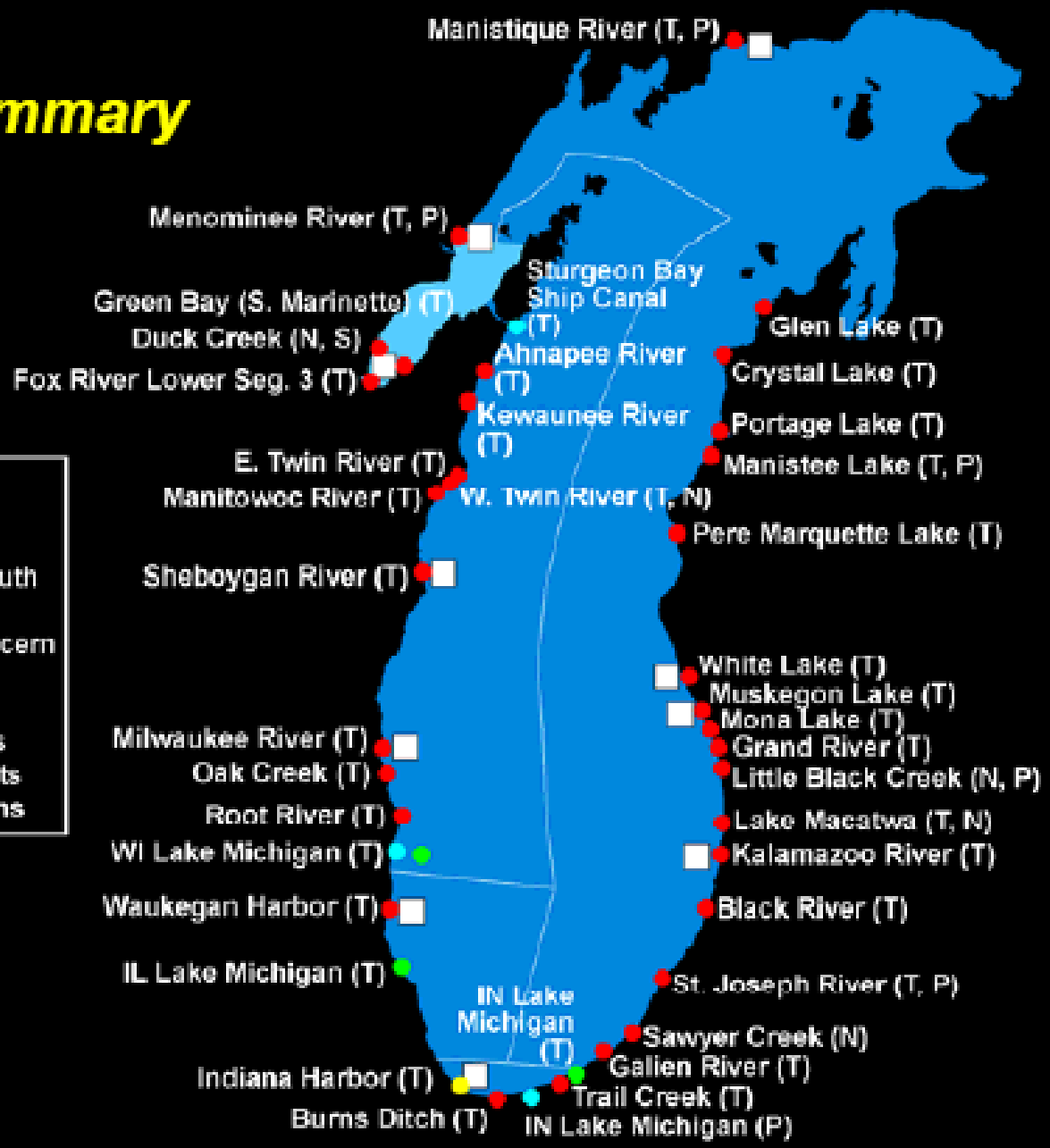
Error bars = 95% confidence limits



Lake Michigan Impairments Summary

tributary mouths, near shore waters, open waters with areas of concern

Lake Michigan LaMP

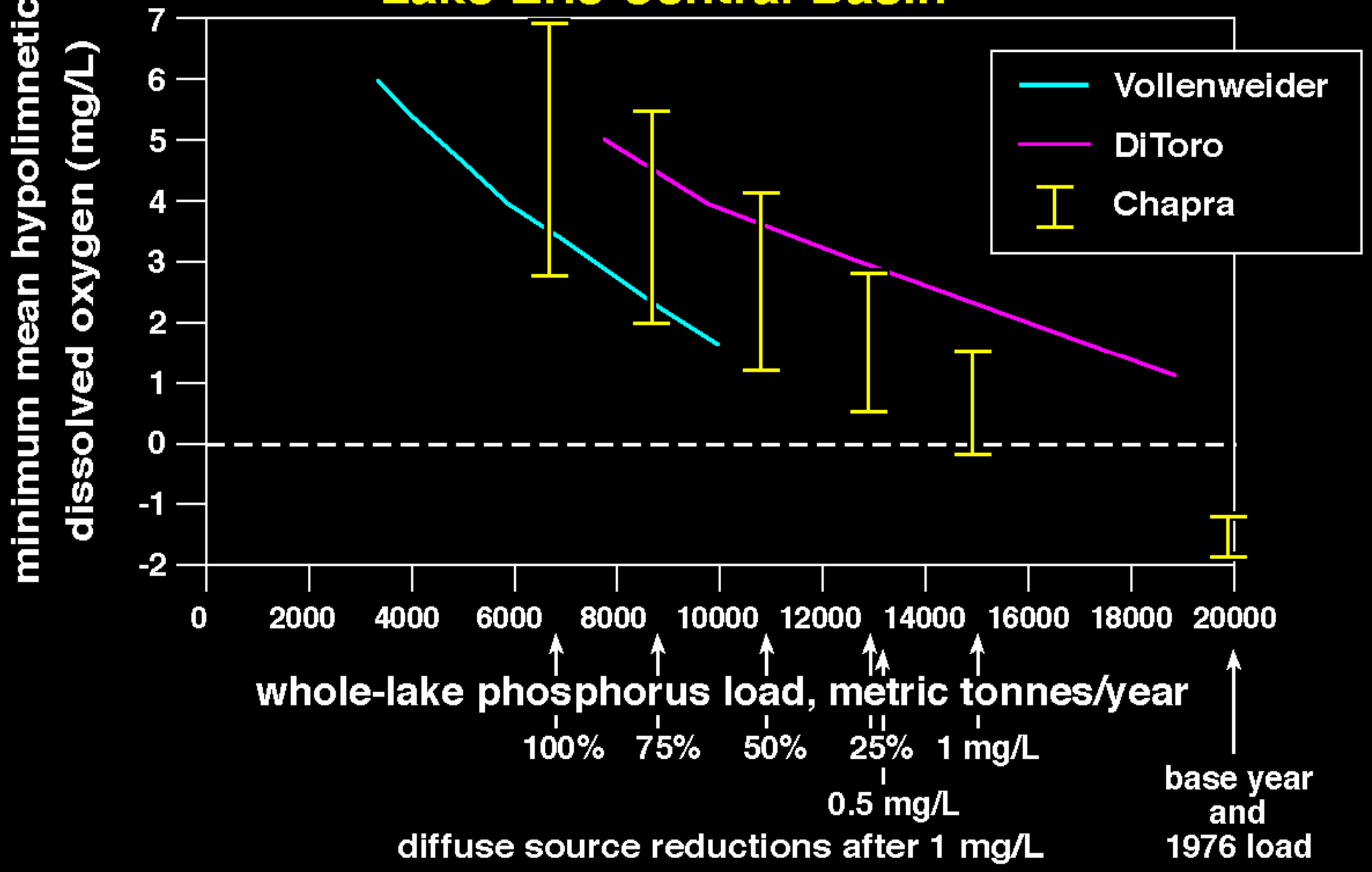


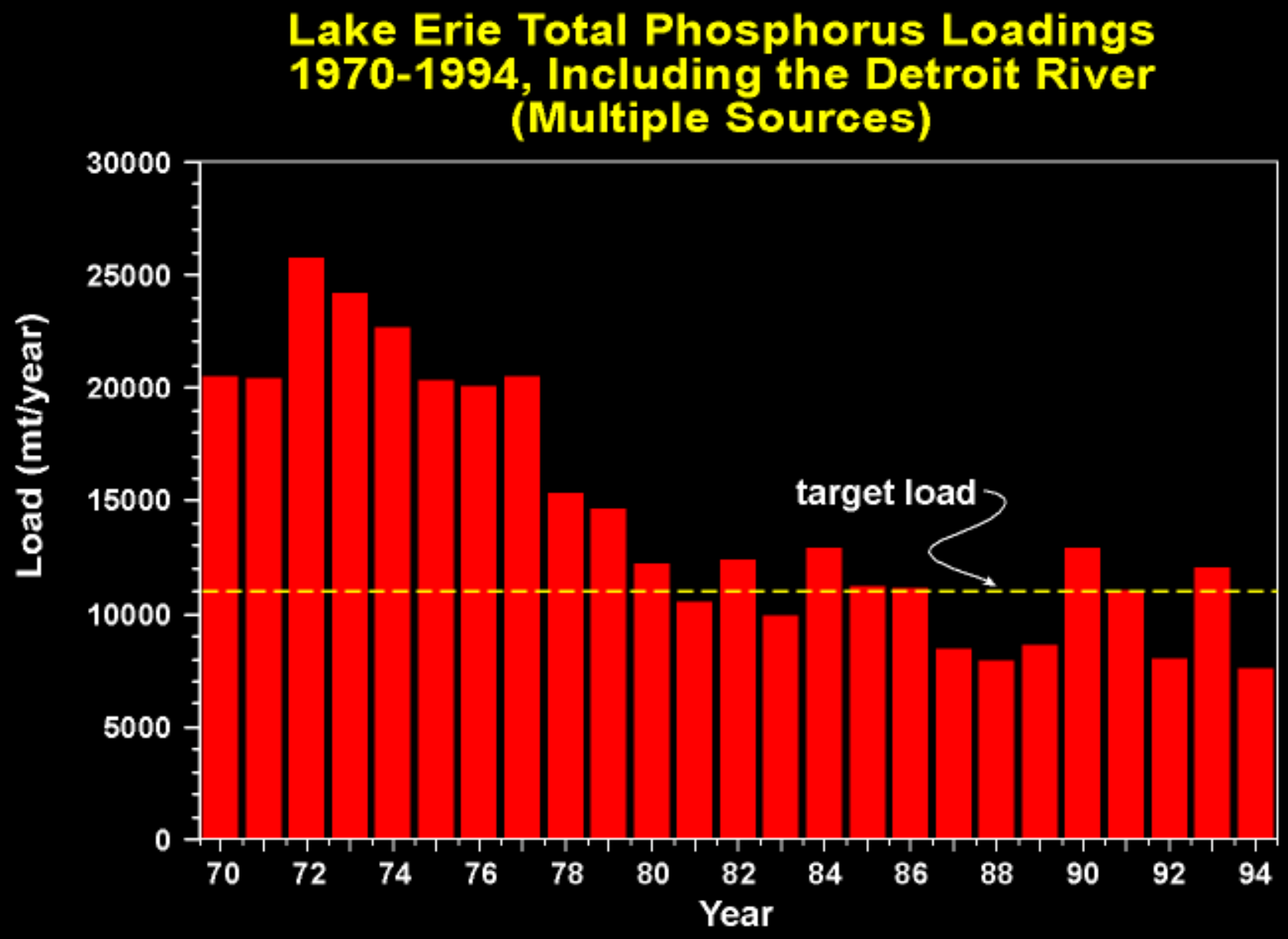
The Approach

Combined Modeling and Monitoring

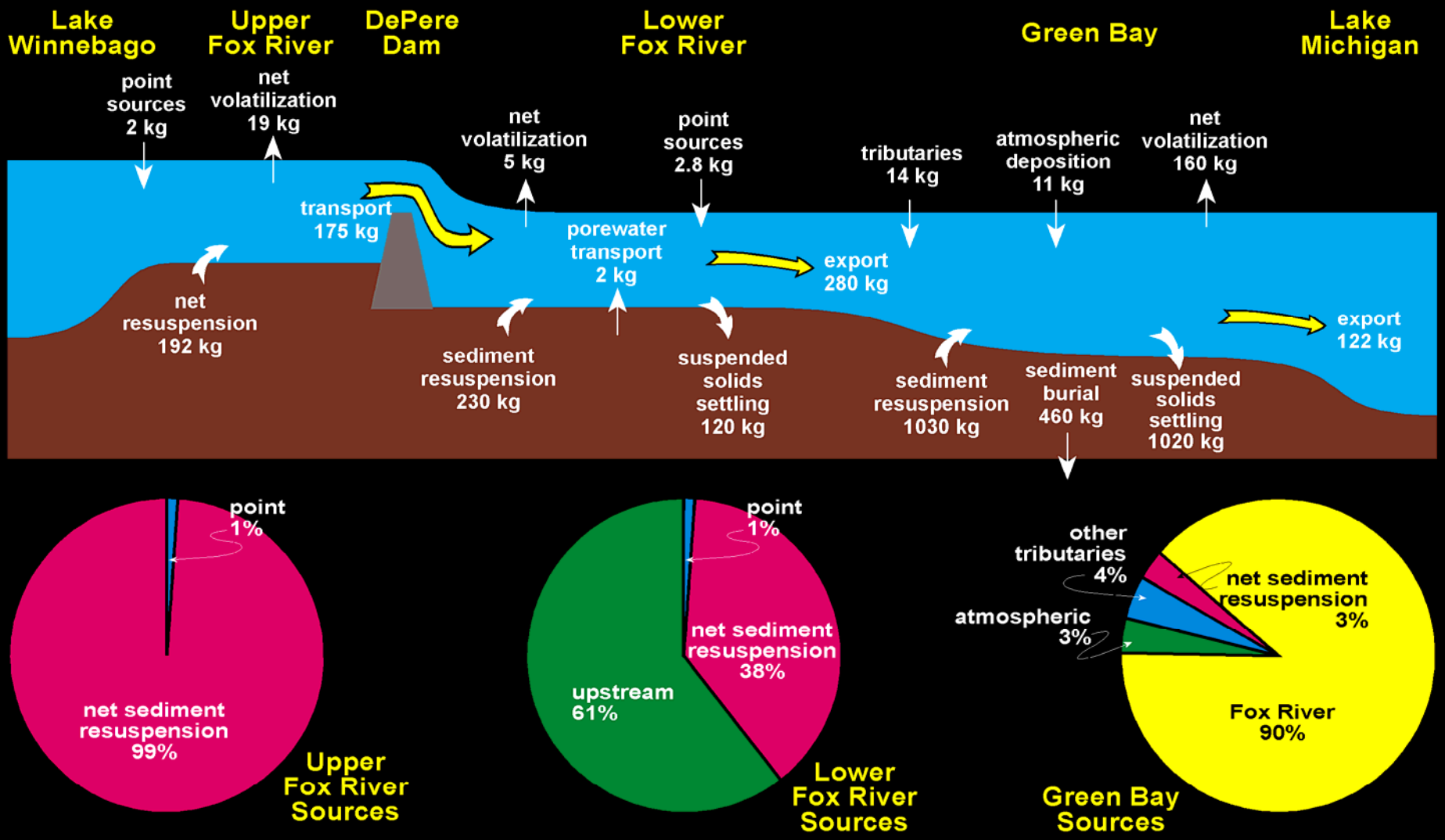
- History of an ecosystem approach in the Great Lakes
- Management of nutrients based on modeling
- Remediation of contaminants based on mass balance work

Phosphorus Load vs. Predicted Minimum Mean Hypolimnetic Dissolved Oxygen Lake Erie Central Basin

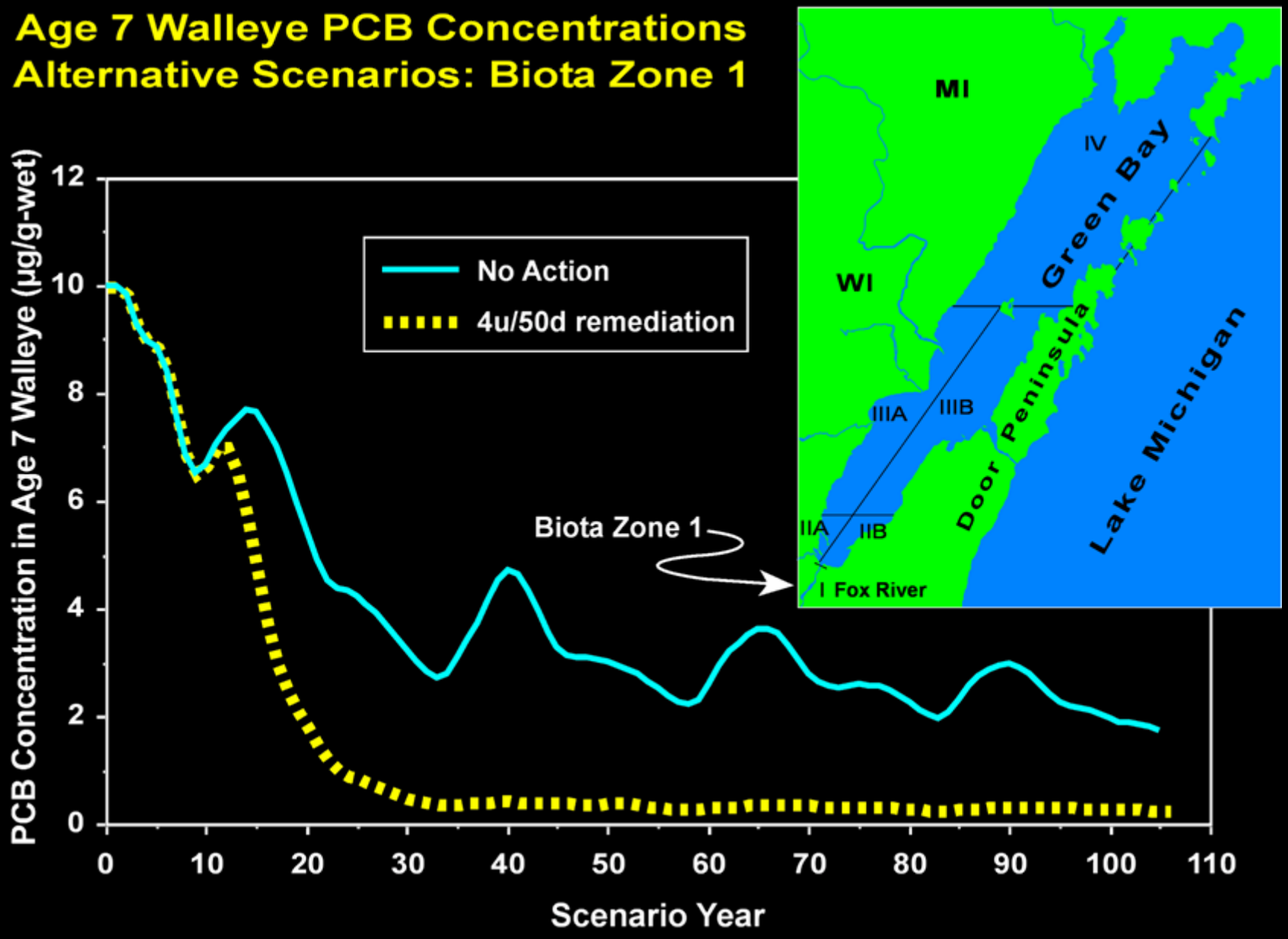



Lake Erie Total Phosphorus Loadings
1970-1994, Including the Detroit River
(Multiple Sources)
Load (mt/year)
30000
25000
20000
15000
10000
5000
0
target load
70
72
74
76
78
80
82
84
86
88
90
92
94
Year

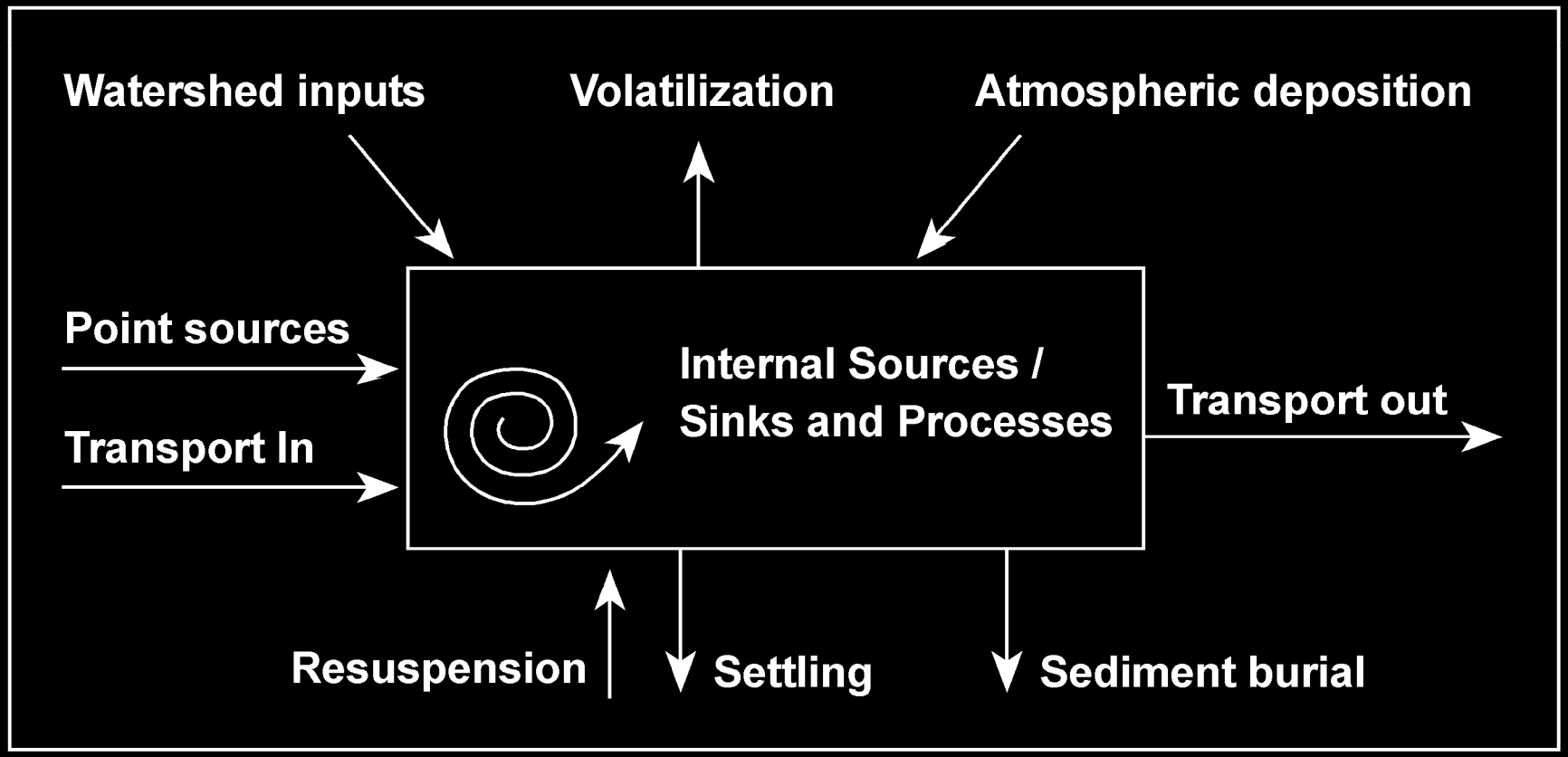
Fox River / Green Bay PCB Mass Balance Fluxes (1989)



Age 7 Walleye PCB Concentrations
Alternative Scenarios: Biota Zone 1



Example Lake Mass Balance



Process

Initial estimates on the quality of data necessary

Monitoring plans based on data quality needs - Performance Based Measurement System (PBMS)

Peer Reviews - Work Plan, Models, Data base, QA process

Lake Michigan Mass Balance Study Goal

to develop a sound, scientific base of information to guide future toxic load reduction efforts at the Federal, State, Tribal, and local levels

Mass Balance Study Objectives

to identify relative loading rates from major tributaries

to evaluate relative loading rates by media

to develop predictive ability

to improve our understanding of cycling and bioavailability of contaminants

Chemicals to Mass Balance

PCB Congeners - *covers large range of physical/chemical properties*

Trans-Nonachlor - *separate pesticide class (cyclopentadienes)*

Atrazine - *current use herbicide*

Total Mercury - *contaminant of current concern*

Lake Michigan Mass Balance Collaborators

U.S. EPA

–Great Lakes National Program Office

– Region 5 Water and Air Divisions / Region 2

– Office of Research and Development

- *Large Lakes Research Station*
- *RTP*

–Office of Air and Radiation - OAQPS

–Office of Water

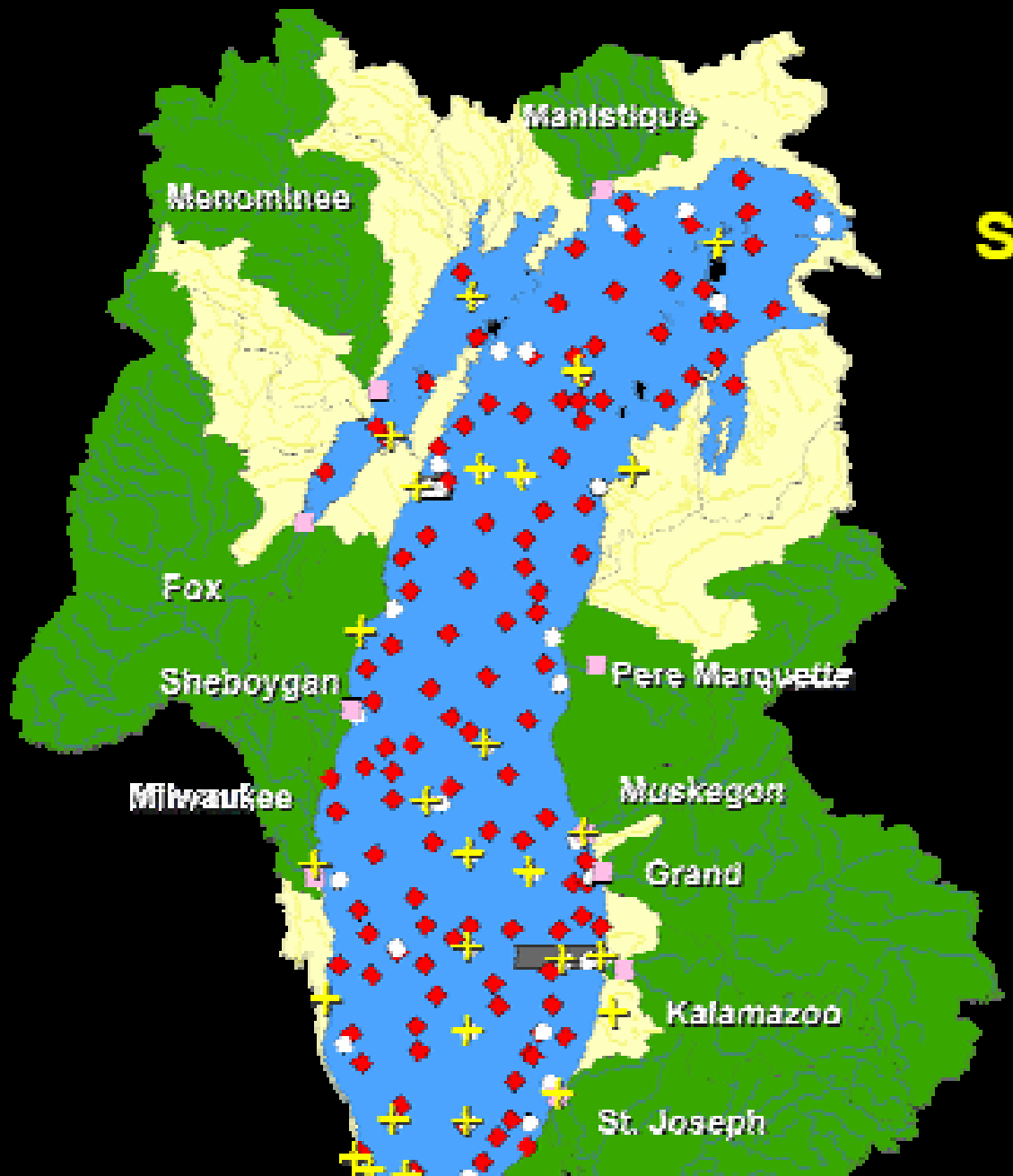
Lake Michigan Mass Balance Collaborators

- United States Geological Survey
  - Biological Research Division (formerly NBS)
  - Water Resources Division
- U.S. Fish and Wildlife Service
- U.S. Department of Energy - Battelle NW
- National Oceanic and Atmospheric Administration
- Environment Canada
- Illinois Department of Natural Resources
- Michigan Department of Environmental Quality
- Michigan Department of Natural Resources
- Indiana Department of Environmental Management
- Wisconsin Department of Natural Resources

Components of Ecosystem Measured

- **Water Column**
  - **Open Lake and Major Tributaries**
- **Fish**
  - **Top predators and Forage Base for Diet Analysis and Contaminant Burden**
- **Lower Pelagic Foodchain**
  - **Species Diversity, Taxonomy, and Contaminant Burden**
- **Sediments**
  - **Cores and Burden Traps for Contaminants and Sedimentation Rate**
- **Atmospheric**
  - **Wet and Dry Deposition in particulate, vapor, and precipitation**

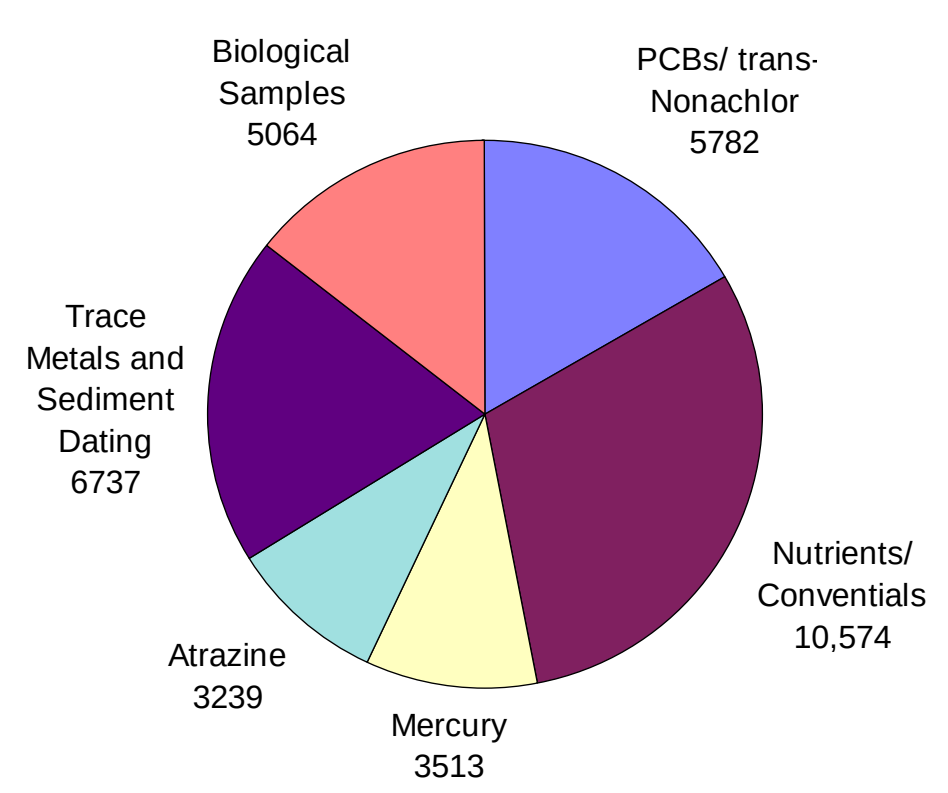
Lake Michigan Sampling Design

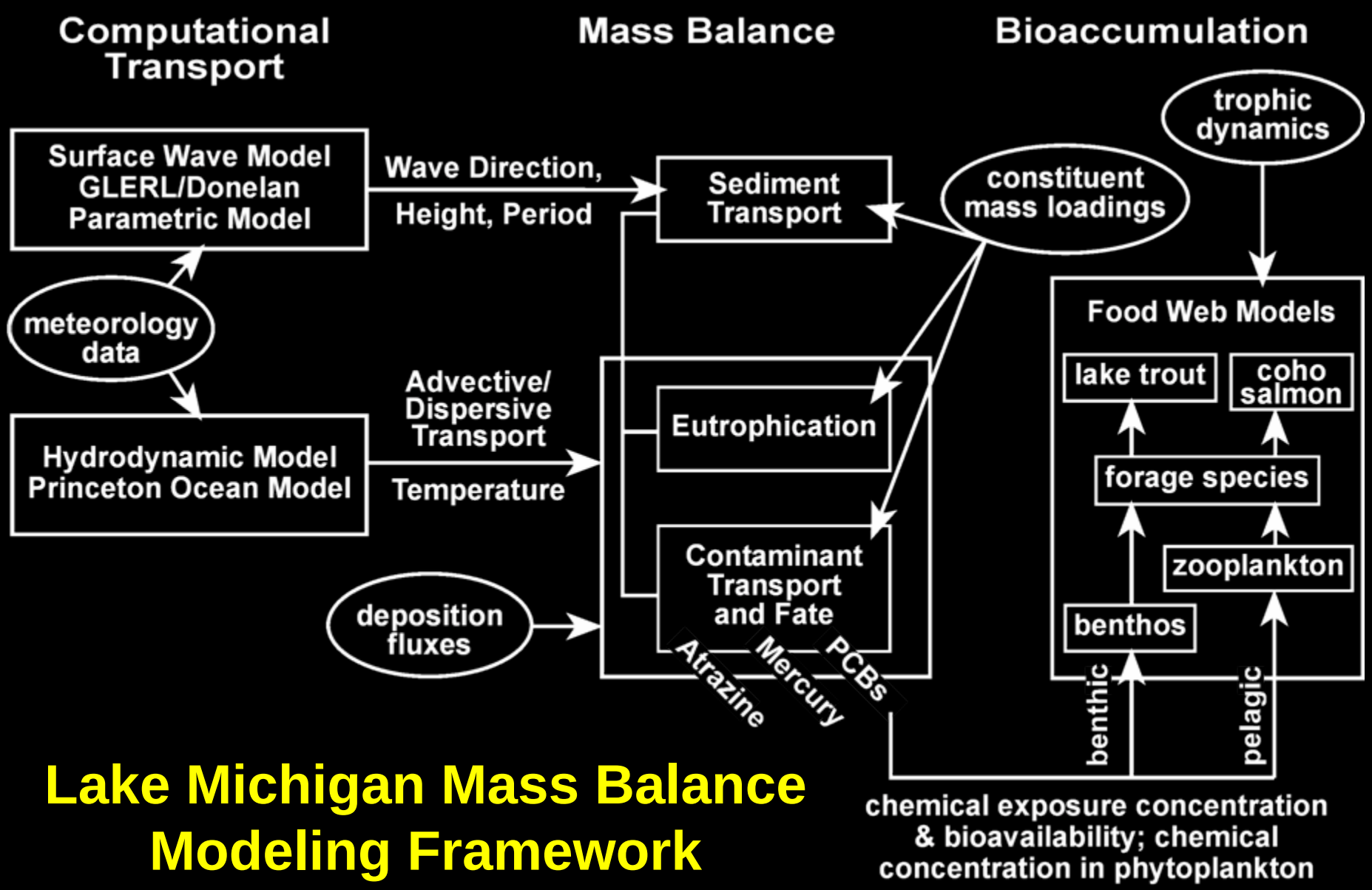


- atmospheric monitoring stations
- sediment samples
- water survey stations
- tributary monitoring stations
- unmonitored tributary basins
- monitored tributary basins
- biota survey boxes

Total Number of Samples

- 38,146 samples with over 1 million result data points



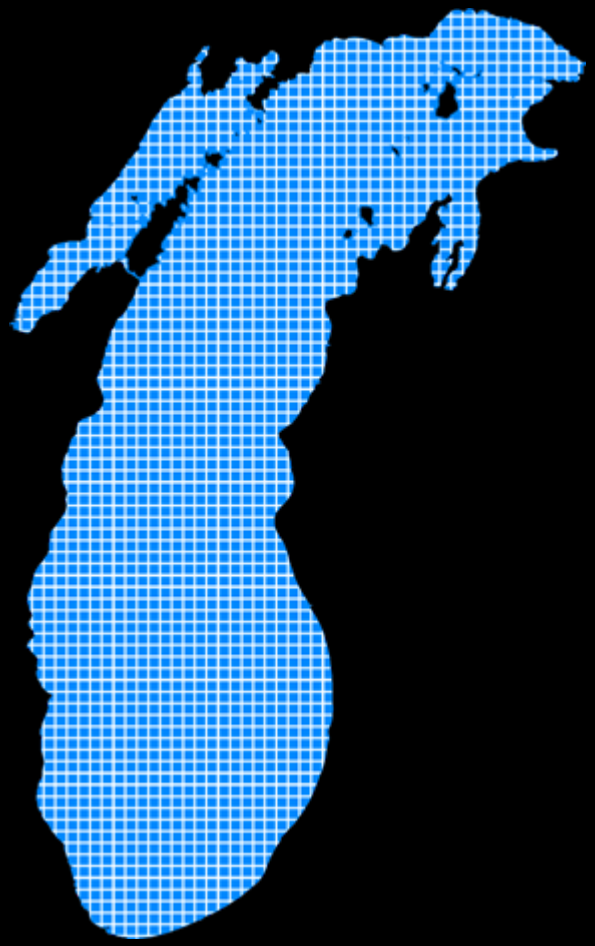


Lake Michigan Mass Balance Modeling Framework

Lake Michigan Mass Balance Project
Water Spatial Resolution/Segmentation Scheme

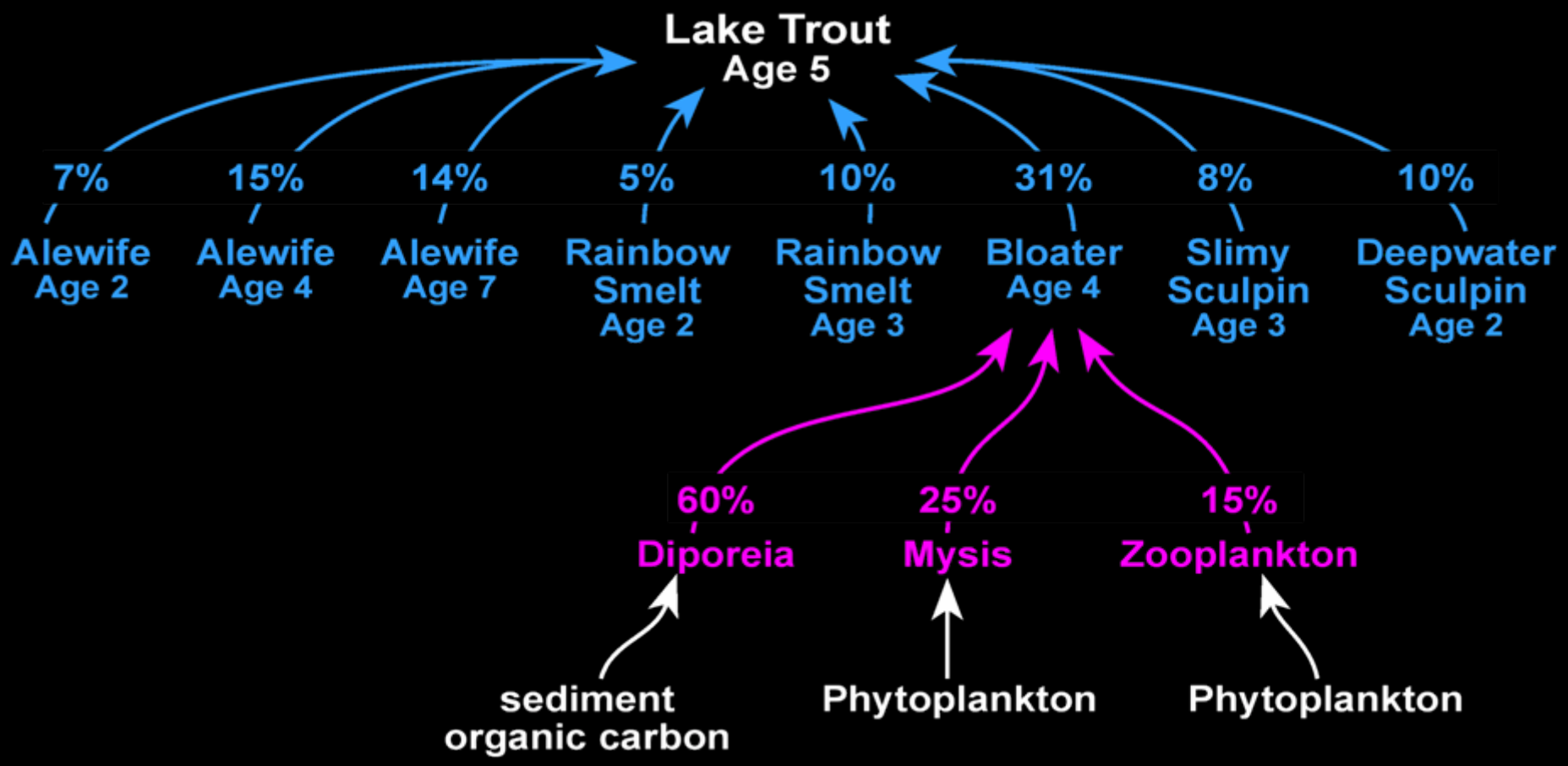
LEVEL 1
Whole Lake

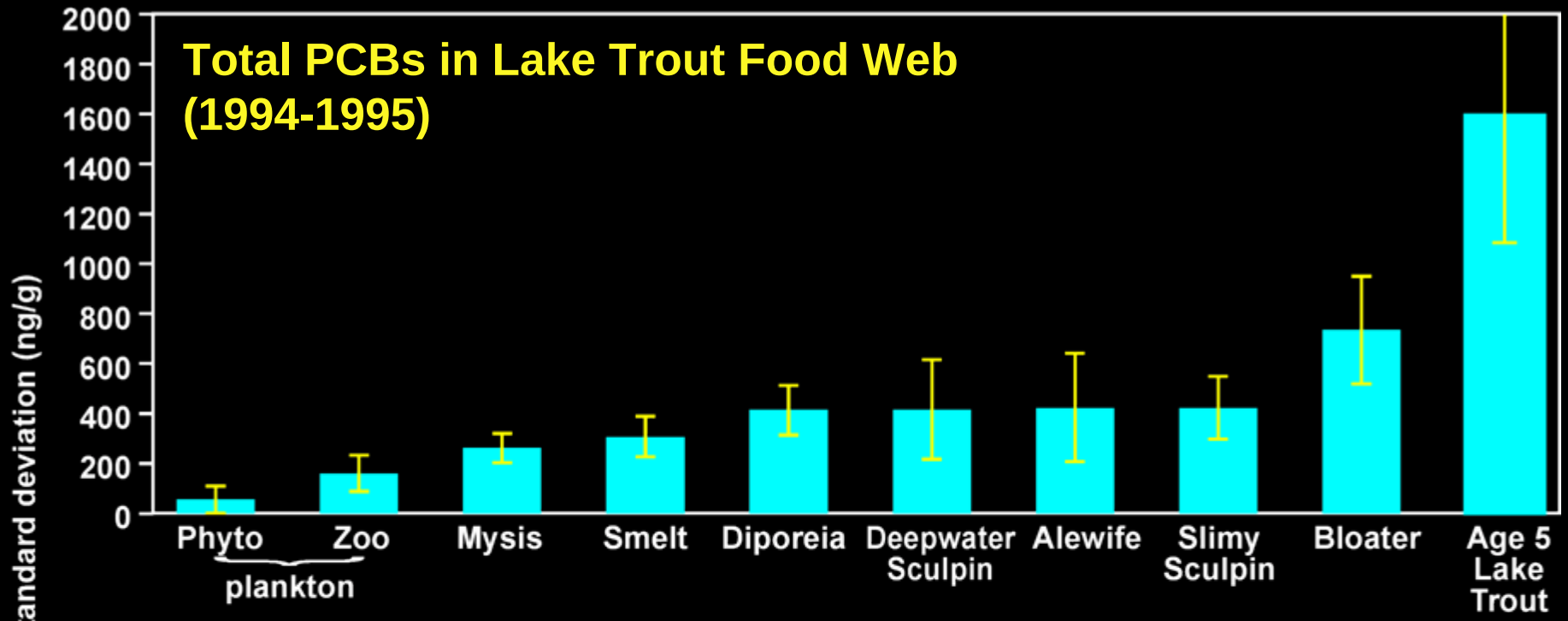
LEVEL 2 - LM-2
10 Surface Segments
41 Water Segments

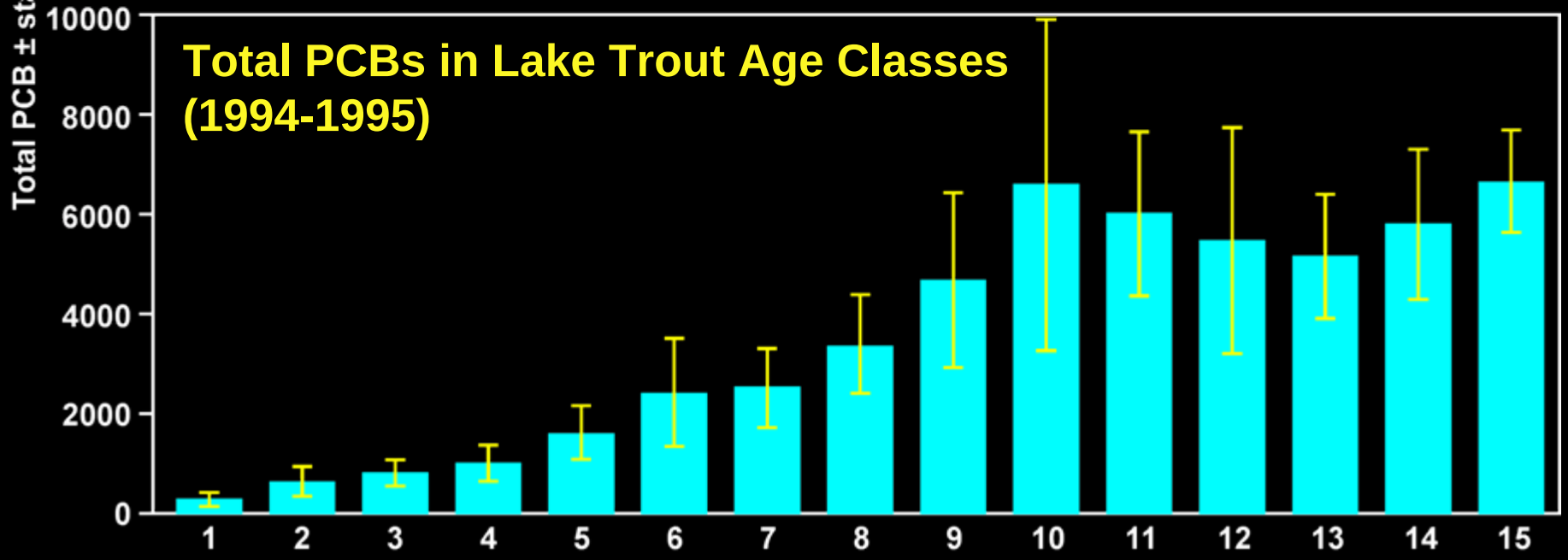


LEVEL 3 - LM-3
(High Resolution 5 x 5 km Grid)
2,318 Surface Segments
44,042 Water Segments
19 “Sigma” Levels

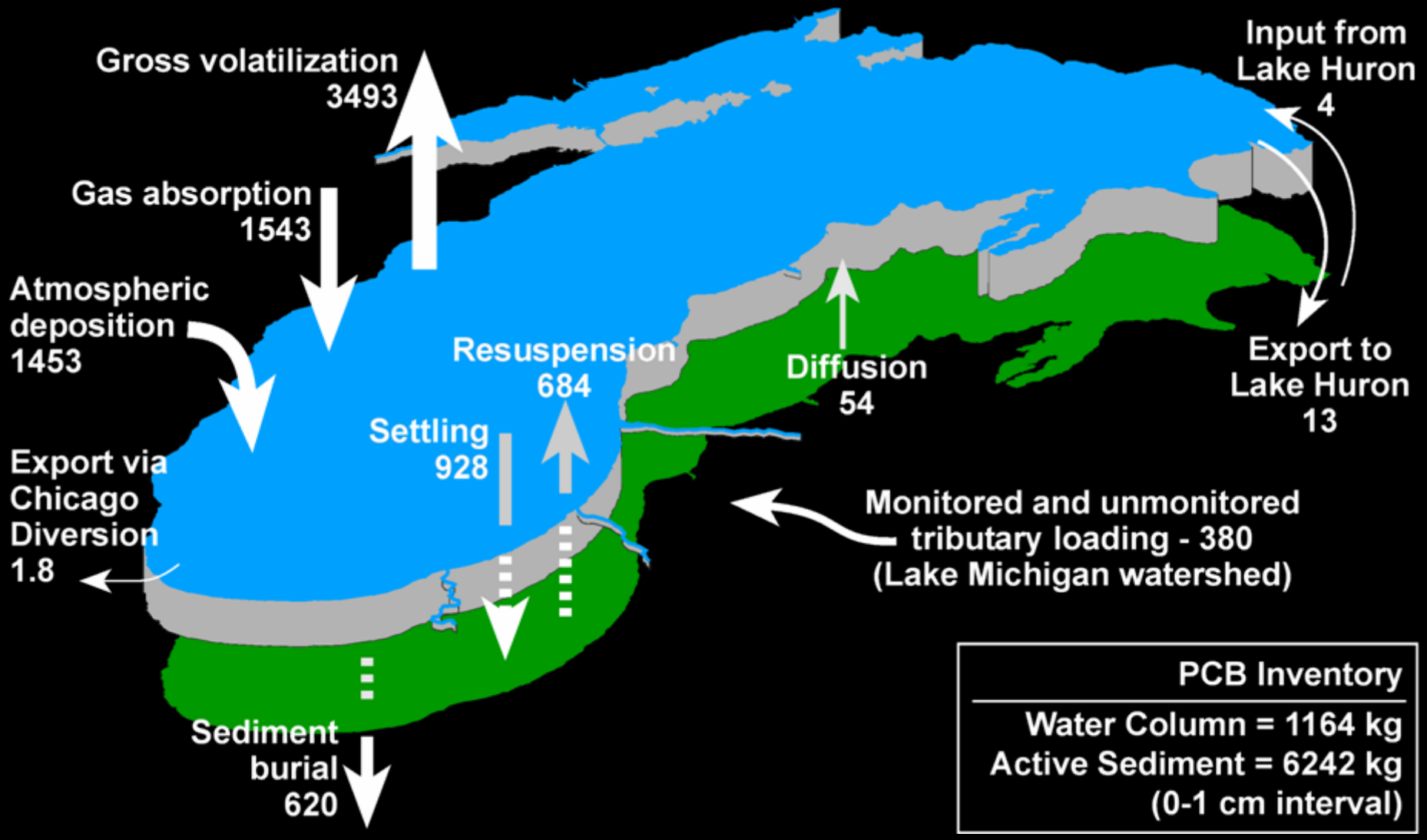
Predator-Prey Feeding Interactions for Age 5 Lake Trout at Saugatuck



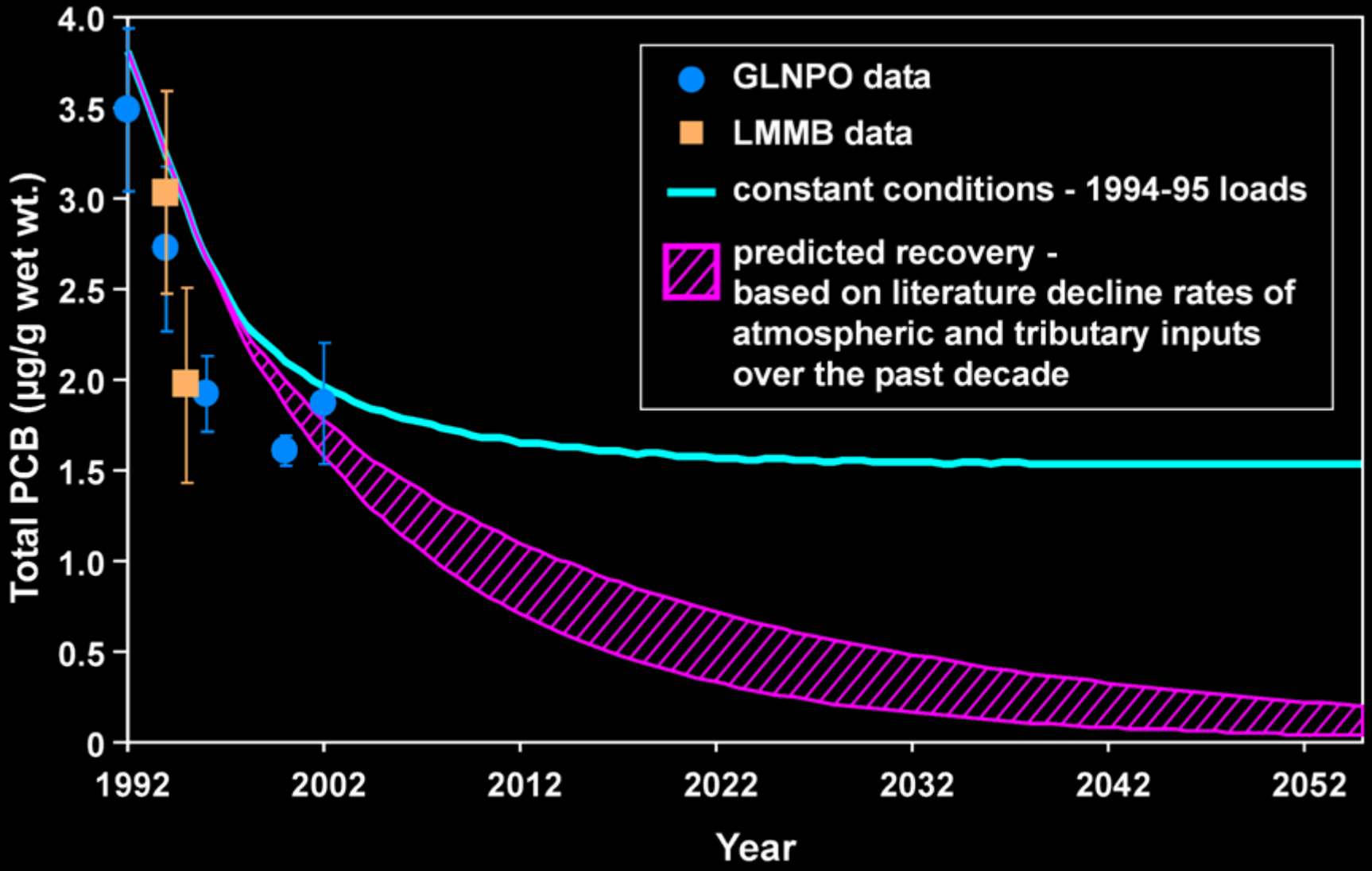

Total PCBs in Lake Trout Food Web
(1994-1995)
Total PCB ± standard deviation (ng/g)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Phyto
Zoo
plankton
Mysis
Smelt
Diporeia
Deepwater Sculpin
Alewife
Slimy Sculpin
Bloater
Age 5 Lake Trout


Total PCBs in Lake Trout Age Classes
(1994-1995)
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

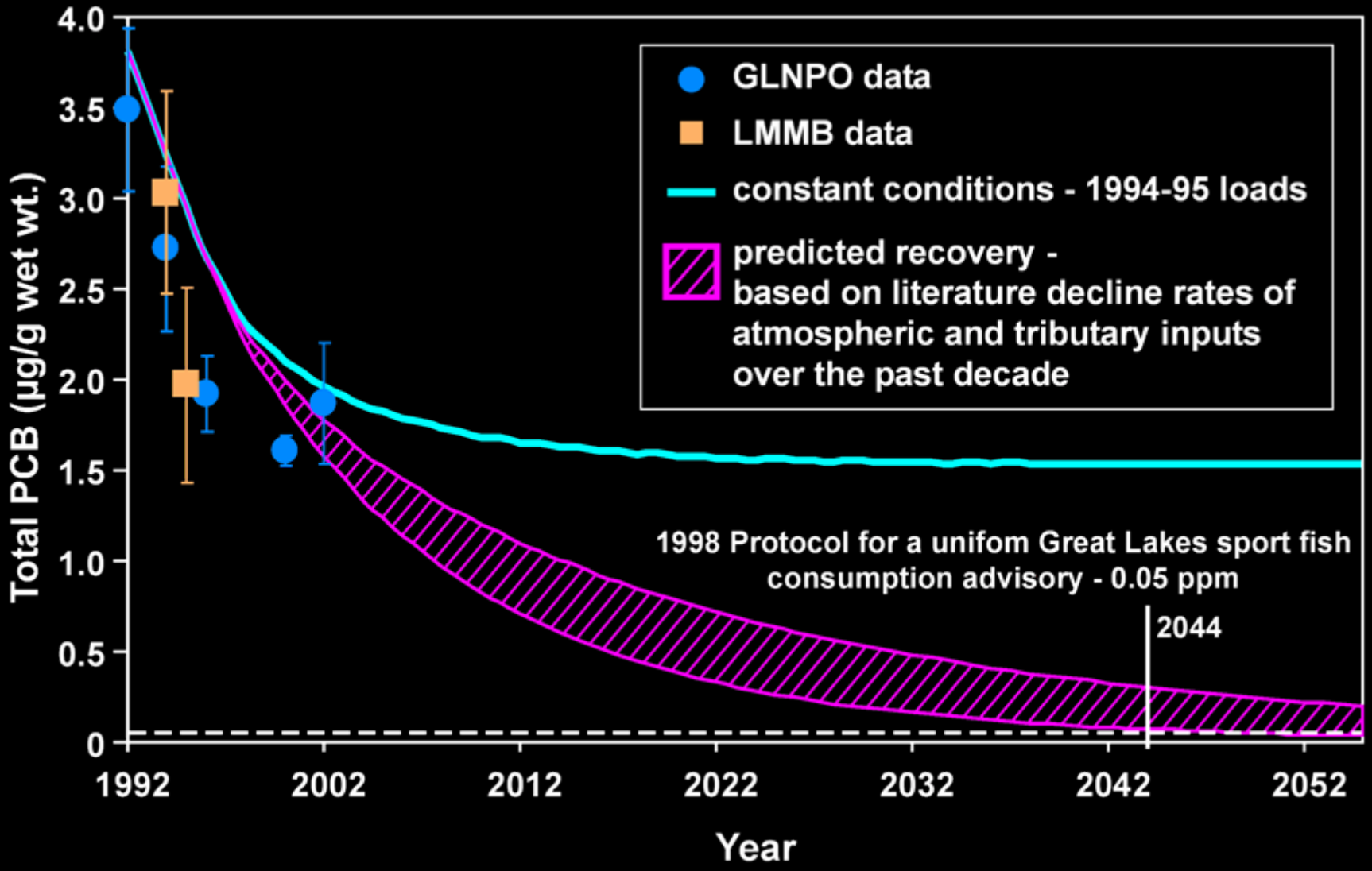
PCB Mass Balance
(1994-1995 – kg/year)



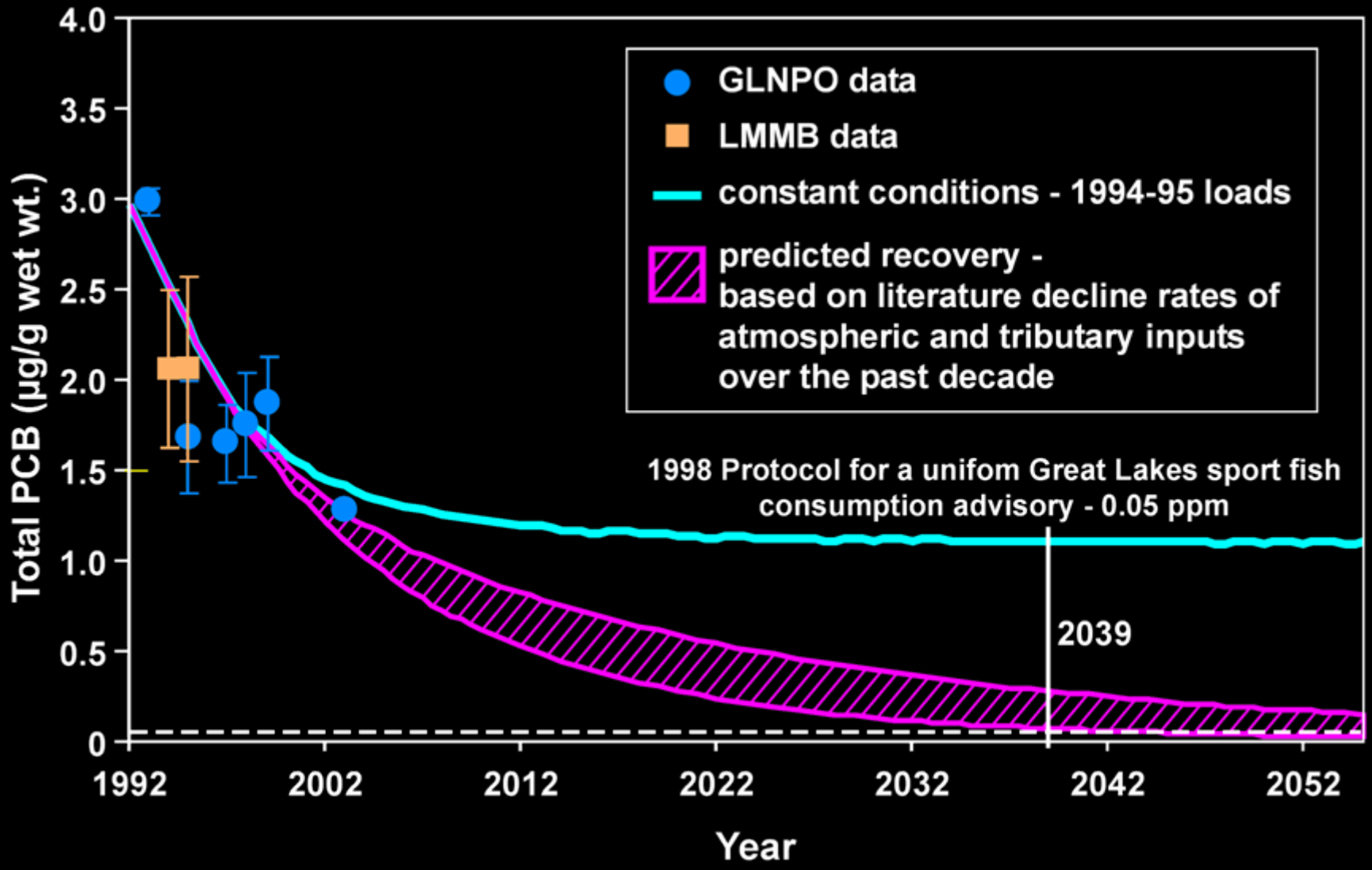
Predicted PCB Concentrations in Age 5.5 Lake Michigan Lake Trout at Saugatuck



Predicted PCB Concentrations in Age 5.5 Lake Michigan Lake Trout at Saugatuck



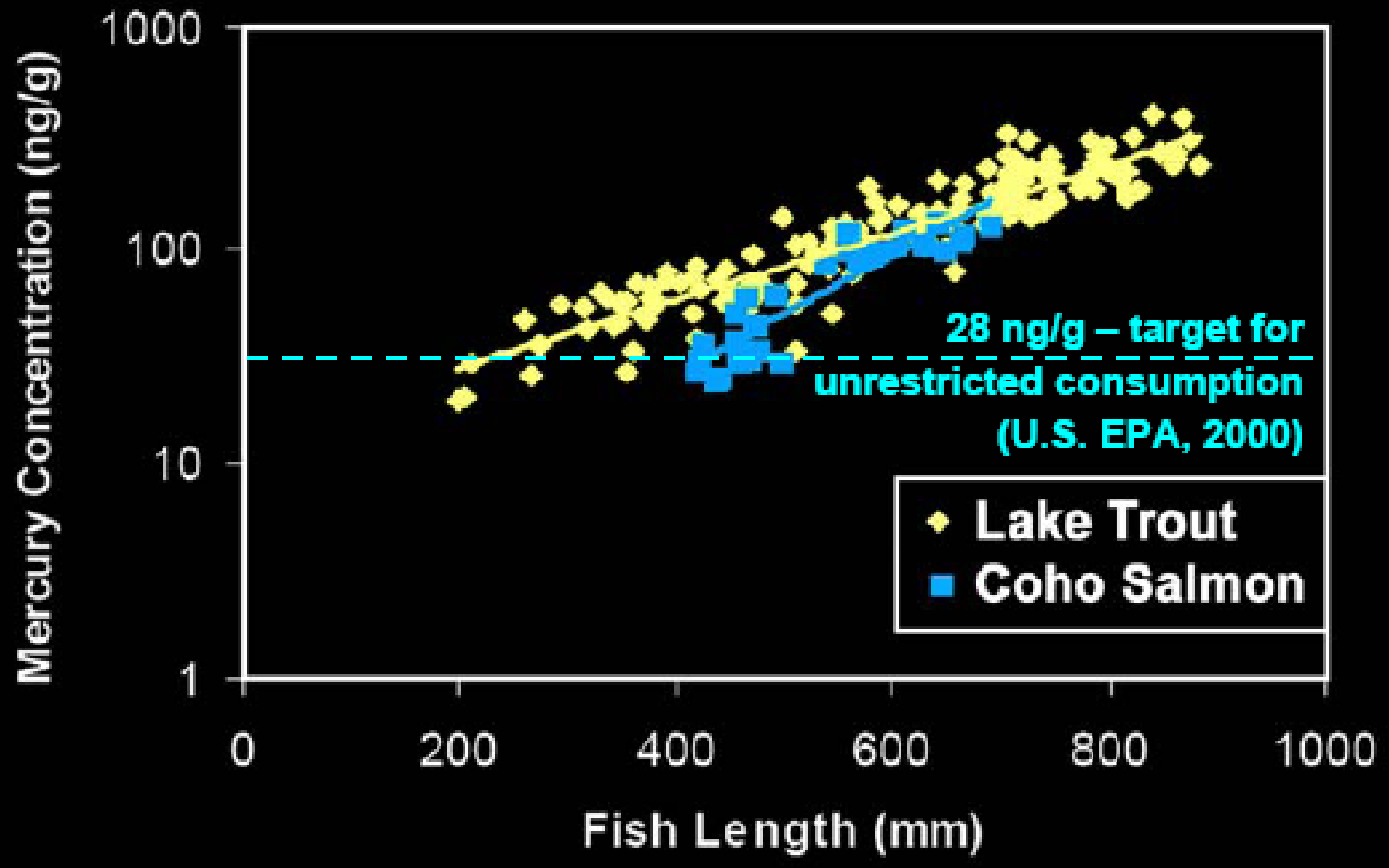
Predicted PCB Concentrations in Age 5.5 Lake Michigan Lake Trout at Sturgeon Bay



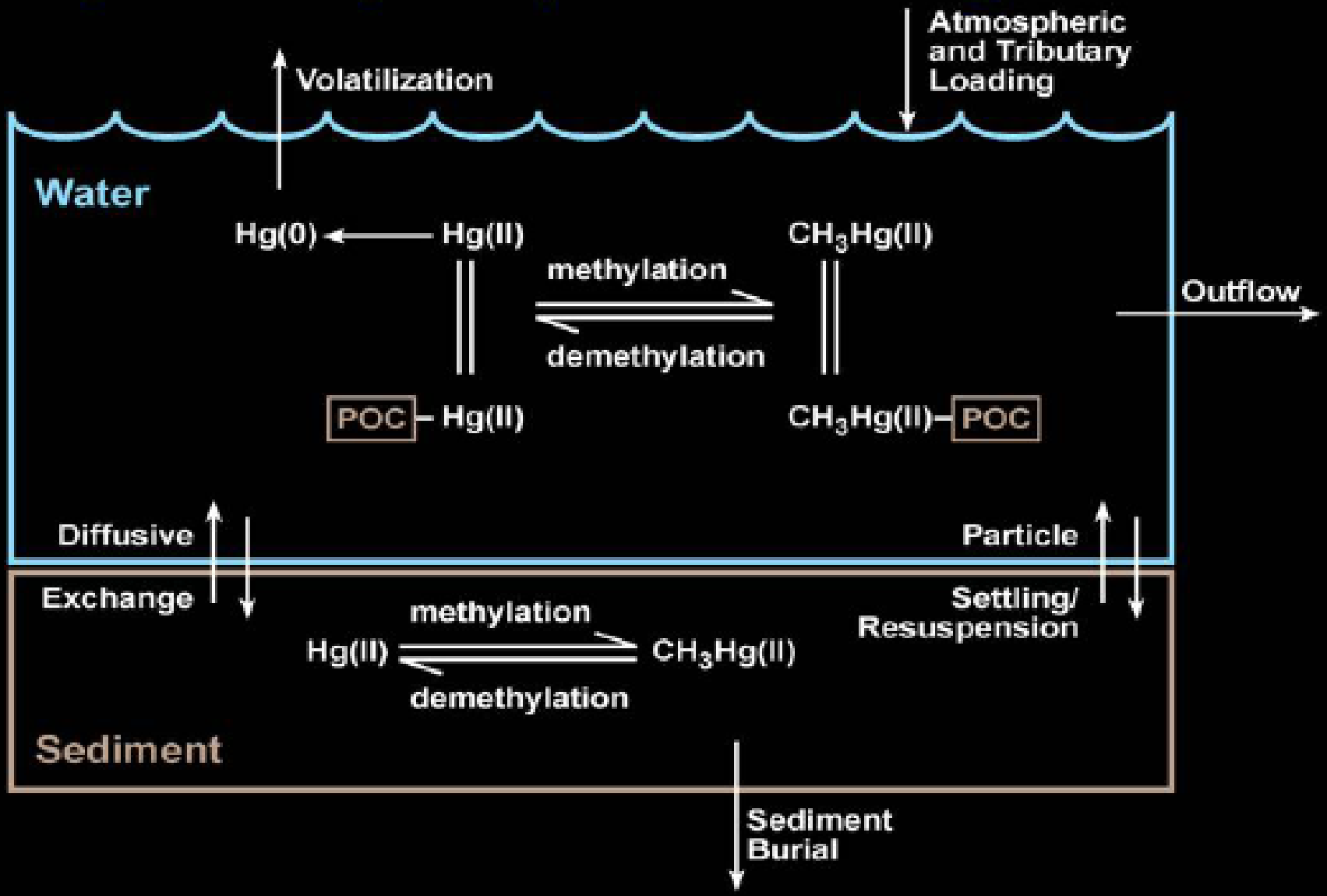
LMMB Major Findings: PCBs

- Forecasted PCB concentrations in lake trout may permit unlimited consumption as early as 2039 at Sturgeon Bay and 2044 at Saugatuck
- PCB trends indicate that concentrations are declining in all media
- Atmospheric deposition is the major source of PCBs to the lake
- Chicago urban area is a substantial atmospheric source of PCBs to Lake Michigan
- There is a dynamic interaction among water, sediments, and the atmosphere where large masses of PCBs cycle into and out of the lake via the atmosphere as vapor phase

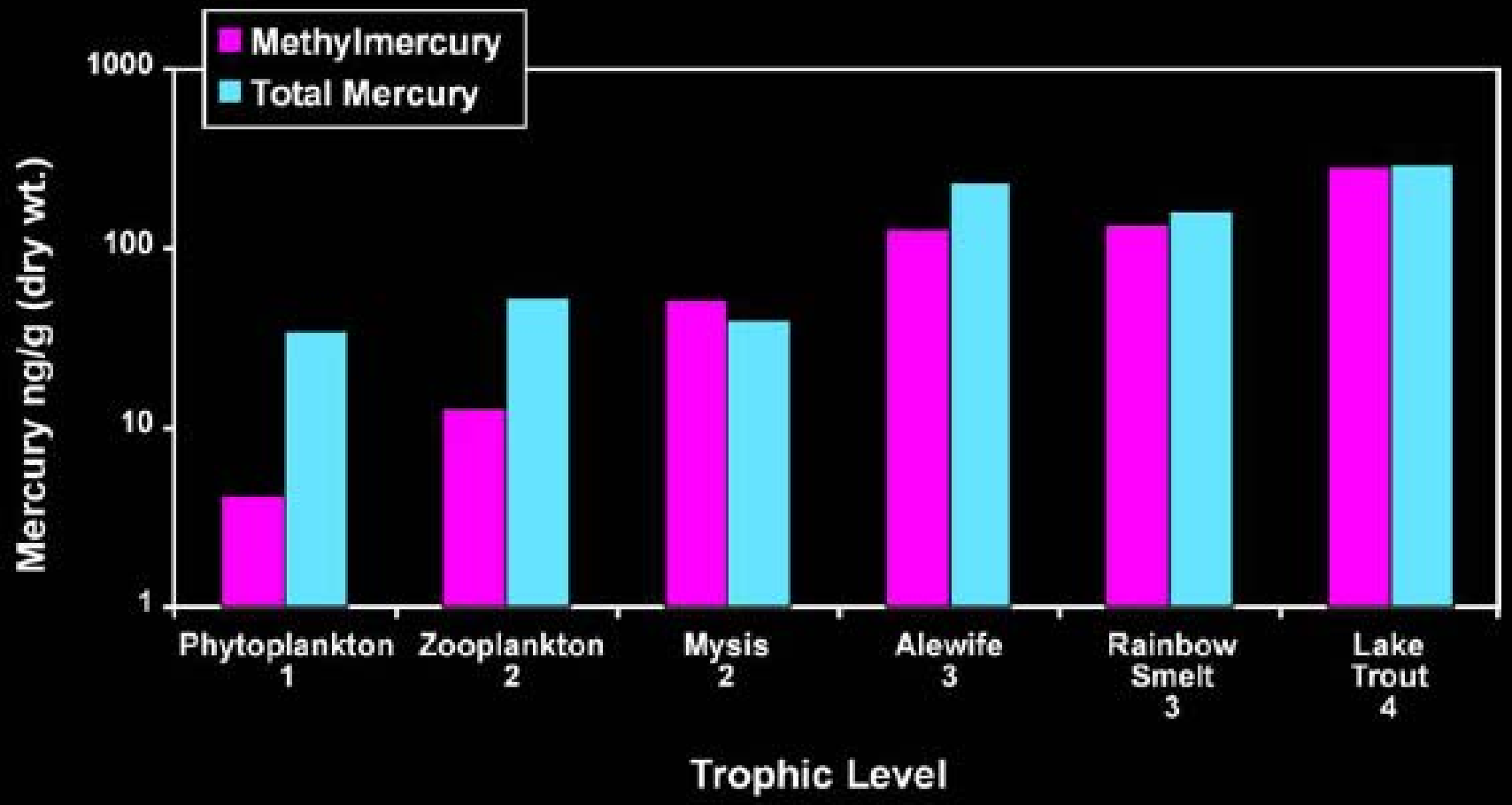
Relationship of Fish Length and Mercury Concentration in Lake Michigan (1994-1995)



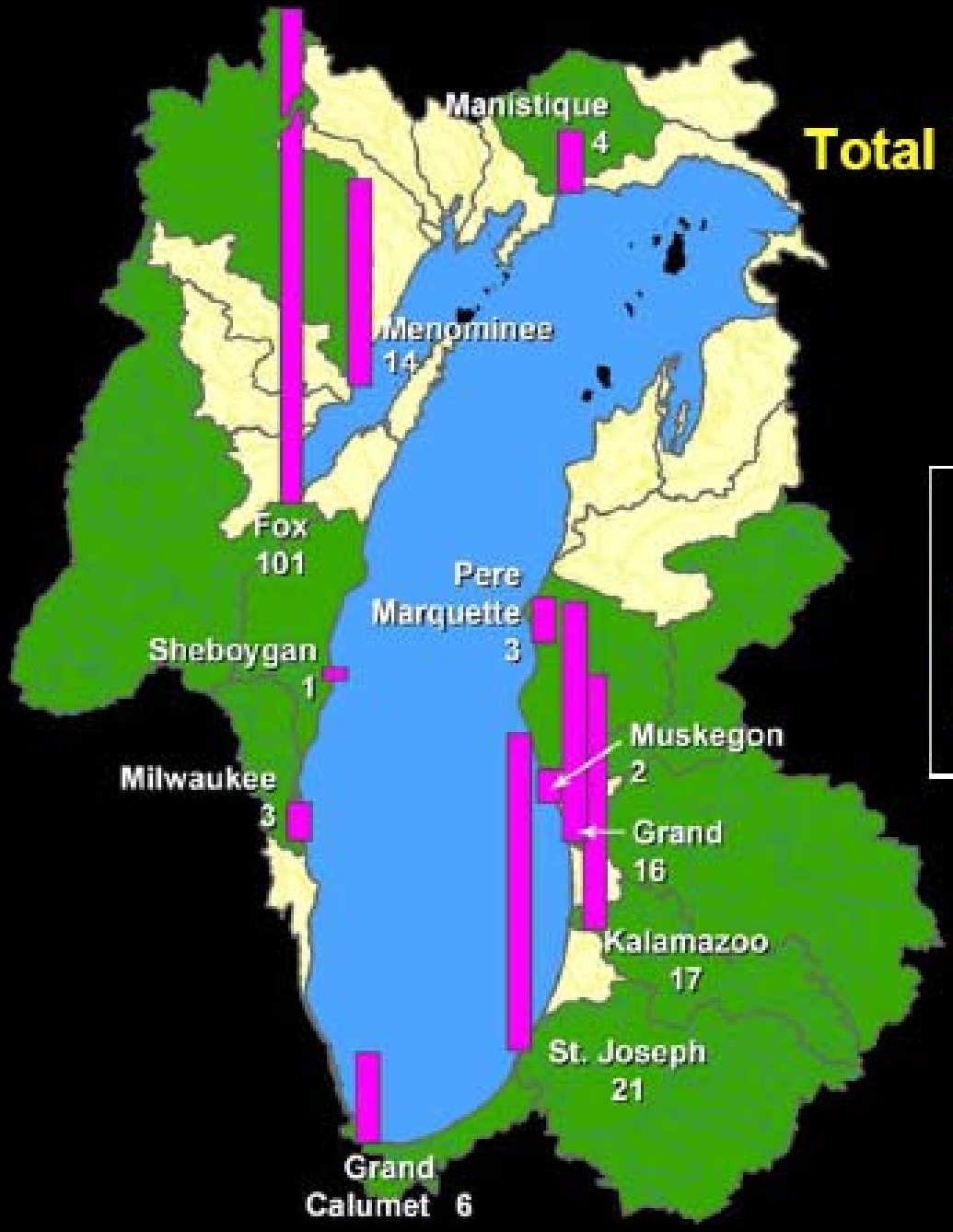
Transport and Transformation Routes of Major Mercury Groups in Lake Michigan



Methylmercury and Total Mercury in Lake Michigan Pelagic Food Chain

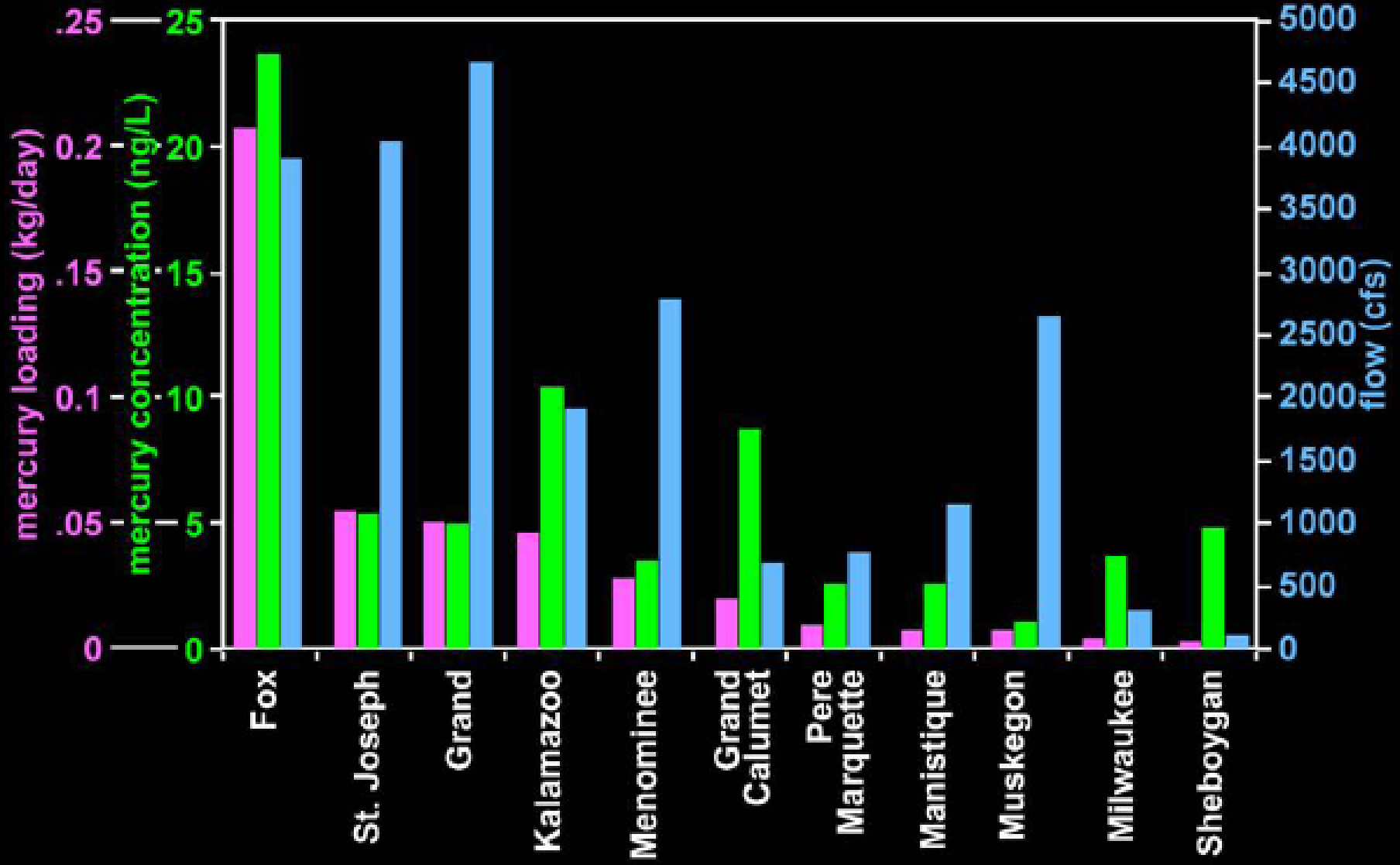


Total Mercury Loads (kg/year) to Lake Michigan from Tributaries, 1995



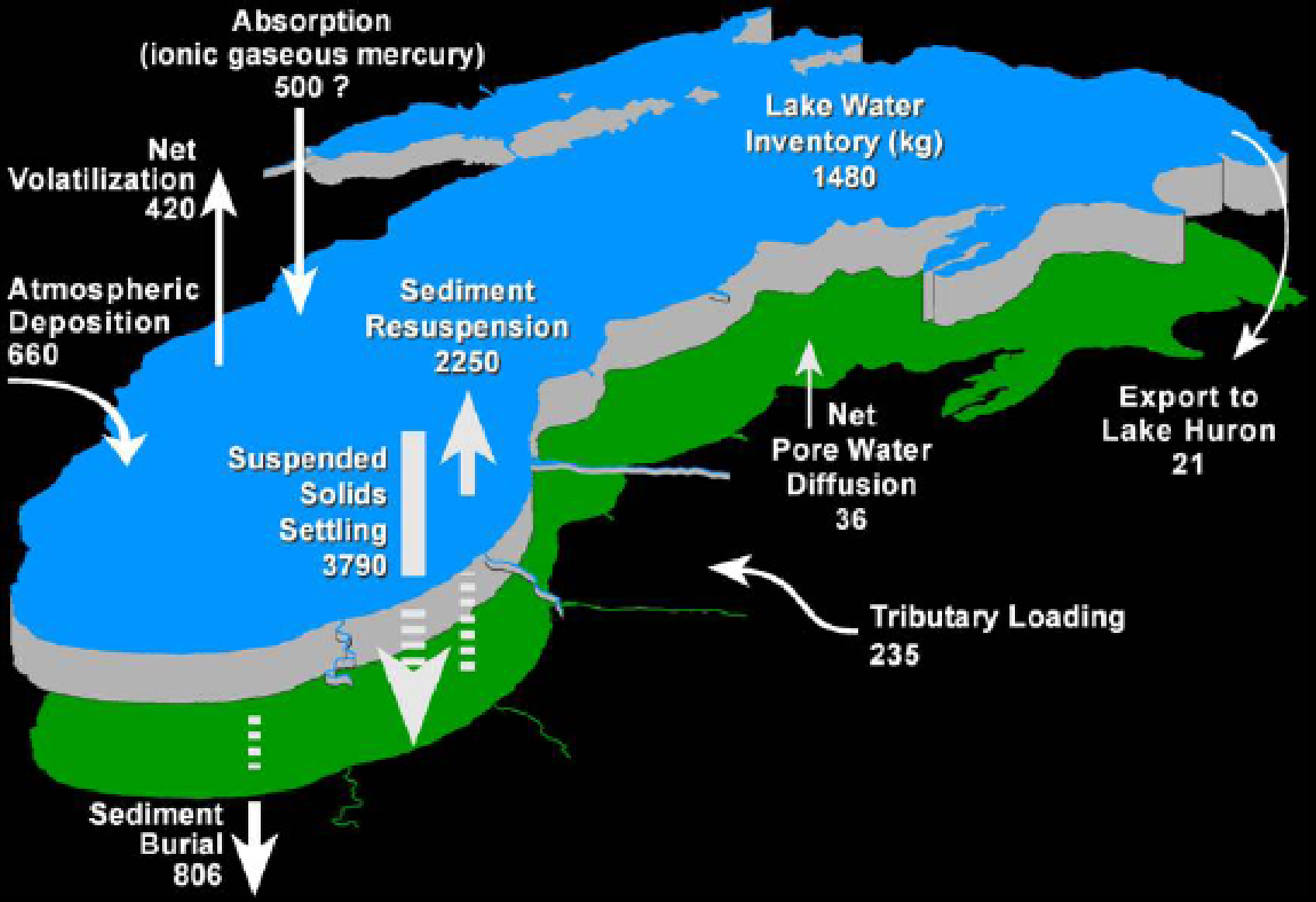
- total mercury loads (kg/year)
- monitored tributary loads: 188
- unmonitored tributary loads: 41

The Relationship Between Tributary Loads, Concentrations, and Flows



Total Mercury Mass Balance for 1994-1995

(Mass Inputs and Outputs in kg/year)



LMMB Major Findings: Mercury

- The major source of mercury to the lake is from atmospheric deposition.
- Most Lake Michigan lake trout and coho salmon exceed the EPA guidelines for unrestricted consumption.
- Modeling results suggest that a significant amount of the existing mercury inventory in the lake is being recycled in the system.

Summary

The Lake Michigan models are world class predictive models

These models are the most robust and integrated that exist for the Great Lakes

They can be used for Lake Michigan for many years to come, and given sufficient multi-media data can be used for other contaminants

This modeling construct can be applied to the other Great Lakes and implemented given the availability of multi-media data for calibration