Lake Michigan Mass Balance Project: Mercury Results

Large Lakes Research Station
(U.S. EPA/ORD/NHEERL/MED)
with
U.S. EPA Great Lakes National Program Office

Goals

Develop a total mercury mass balance for Lake Michigan based on data collected during 1994 - 1995.

Identify major sources and sinks for total mercury in the lake and gain a better understanding of transport and fate of mercury in the lake system.

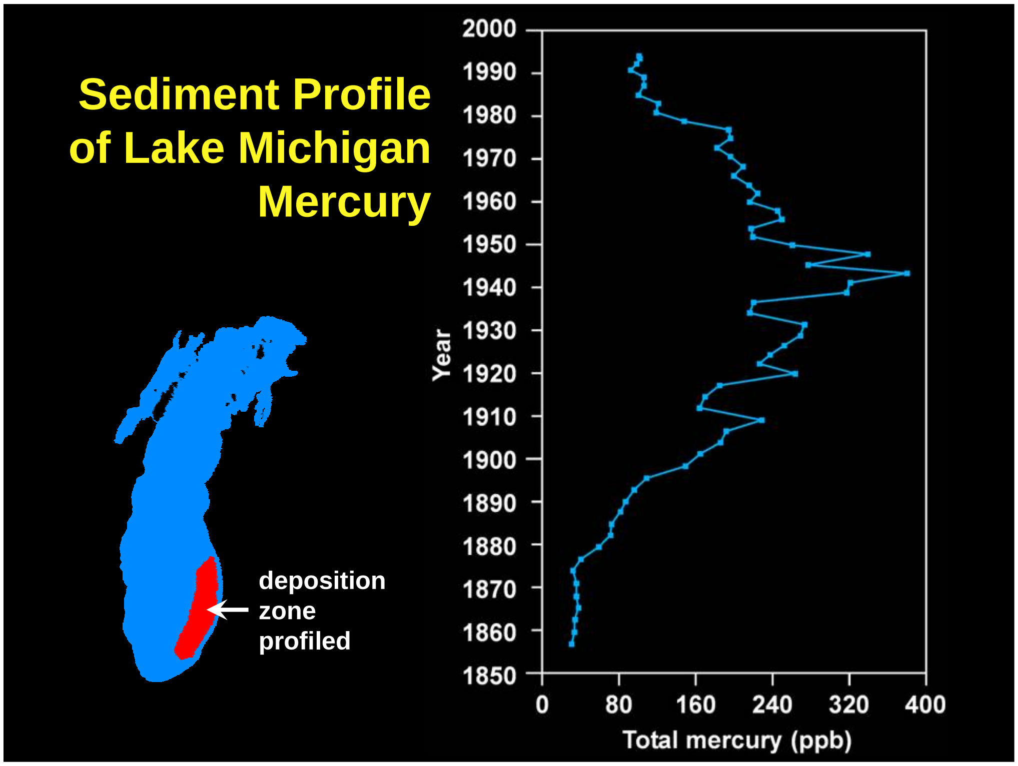
Evaluate mercury concentrations in the Lake Michigan food chain.

Major Findings

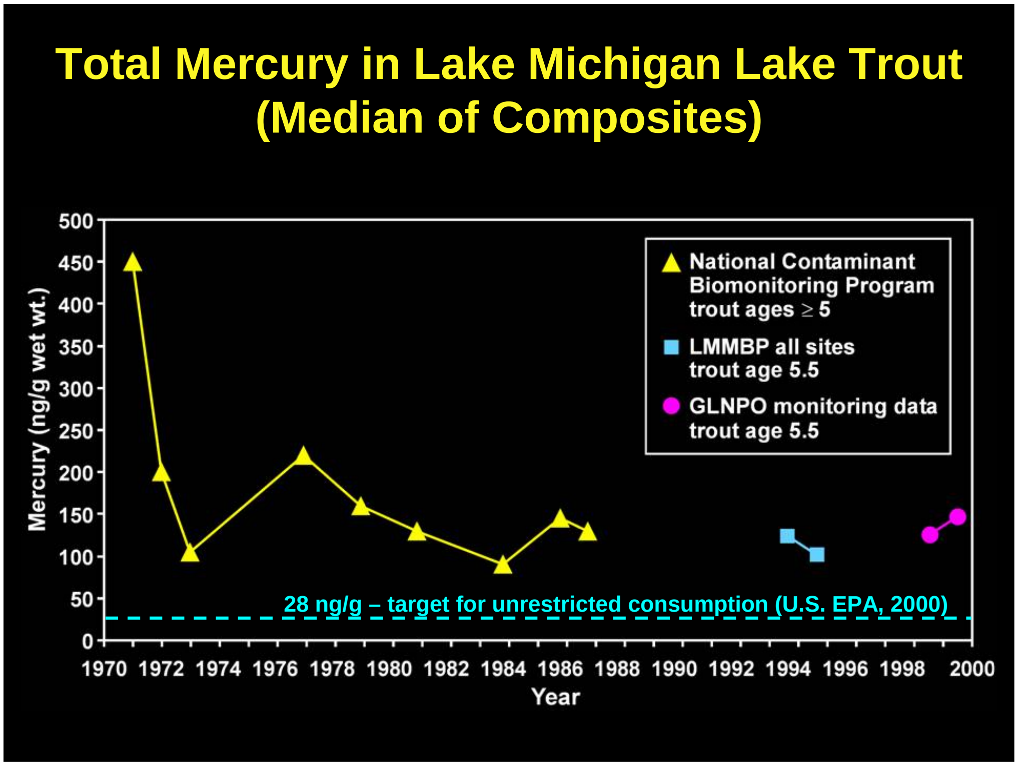
The major source of mercury to the lake is from atmospheric deposition.

Most Lake Michigan lake trout and coho salmon exceed the EPA guidelines for unrestricted consumption.

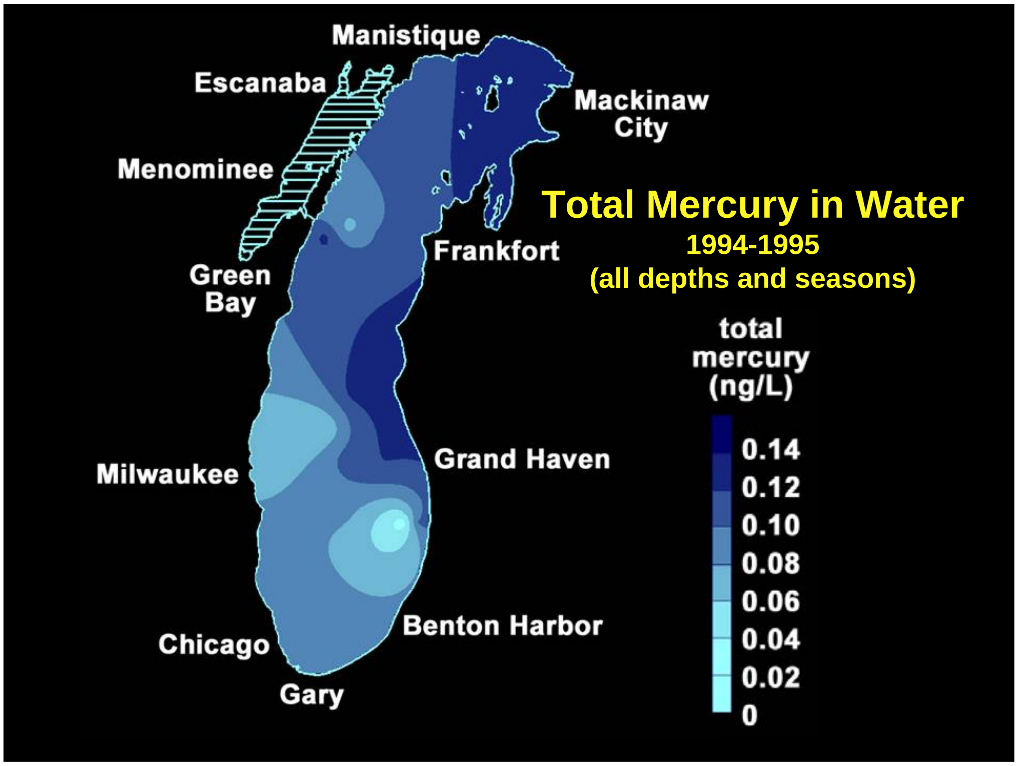
Modeling results suggest that a significant amount of the mercury settling out of the water is being recycled back into the system.



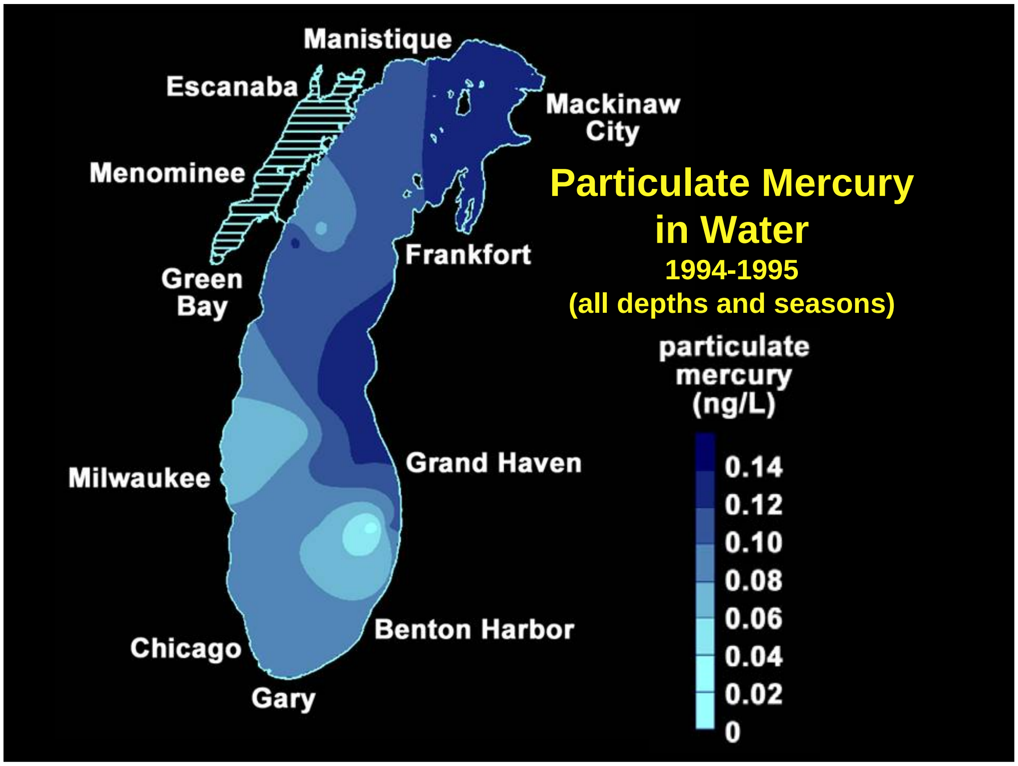
Mercury concentrations in sediment cores are very useful to get an idea of historical trends. Here are the results of a sediment core obtained from the deposition zone shown in red on the map. Note that the concentration of mercury peaked in the mid 1940's and has been on a decline since then.



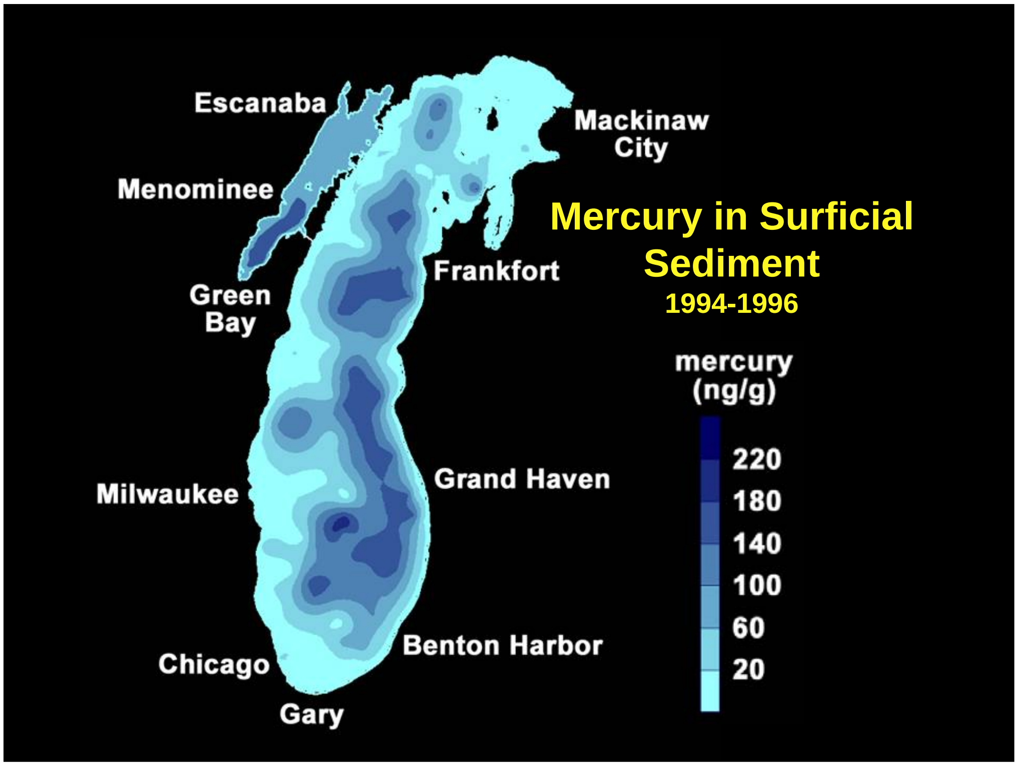
Mercury concentrations in lake trout have been following a similar pattern of decline as seen in the sediment core. Note that since the late 1970's the concentrations seems to have leveled-off. The U.S. EPA target for unrestricted consumption of fish is shown here. Note that all of the composites exceed this target.



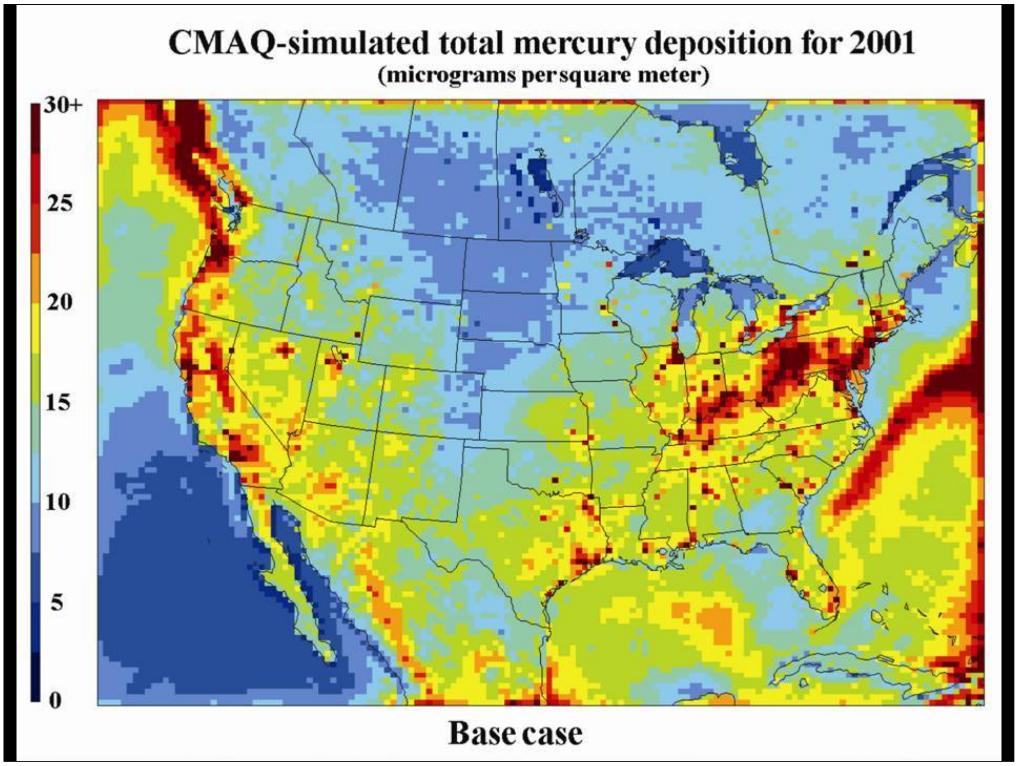
Manistique
Escanaba
Mackinaw City
Menominee
Total Mercury in Water
1994-1995
(all depths and seasons)
Frankfort
Green Bay
total mercury (ng/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
Milwaukee
Grand Haven
Benton Harbor
Chicago
Gary



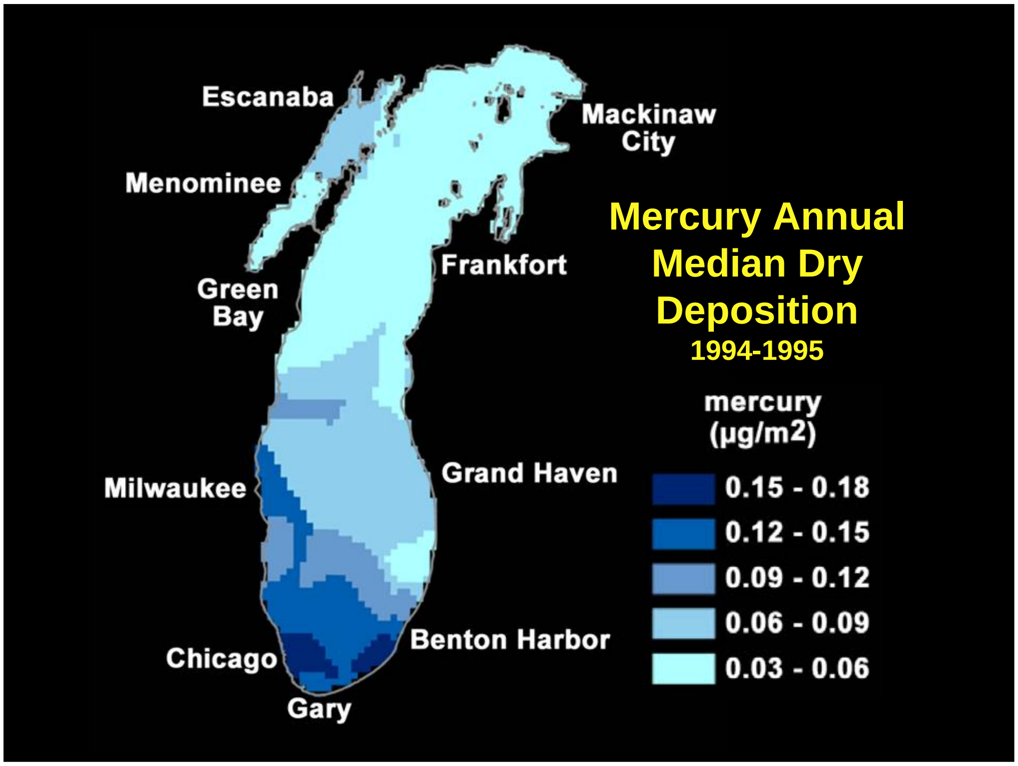
This graphic depicts mercury associated with particulates in the water column. The pattern is similar to that shown on the previous slide for total mercury in water.



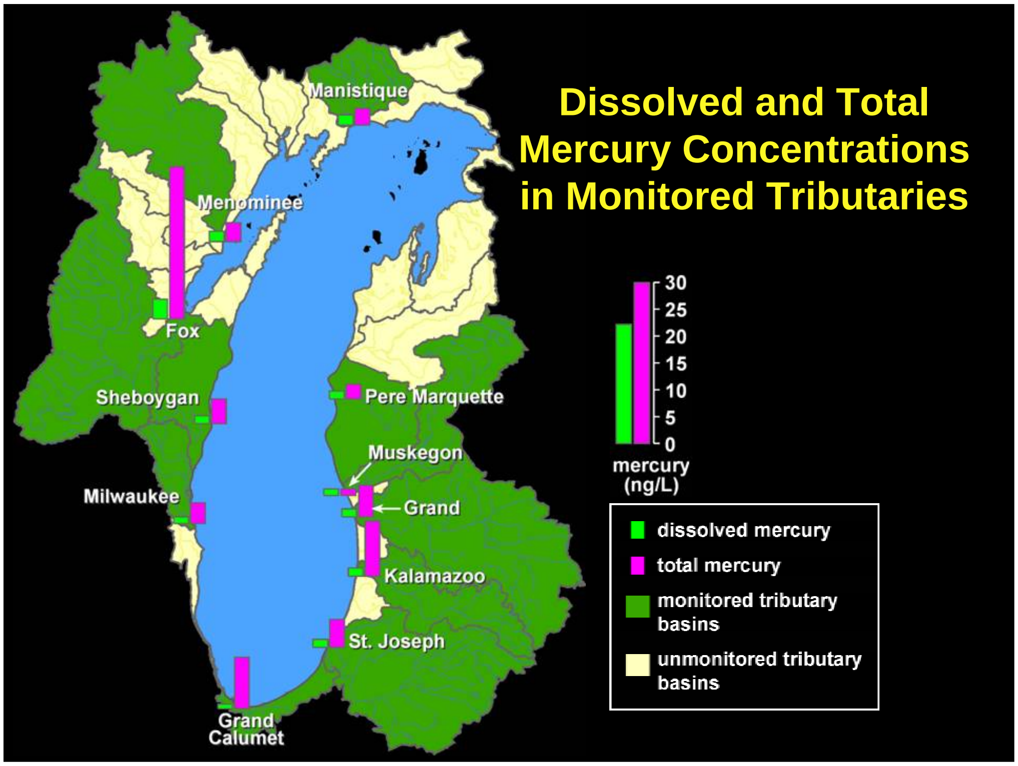
Higher concentrations of mercury are found in the depositional zones in the lake.



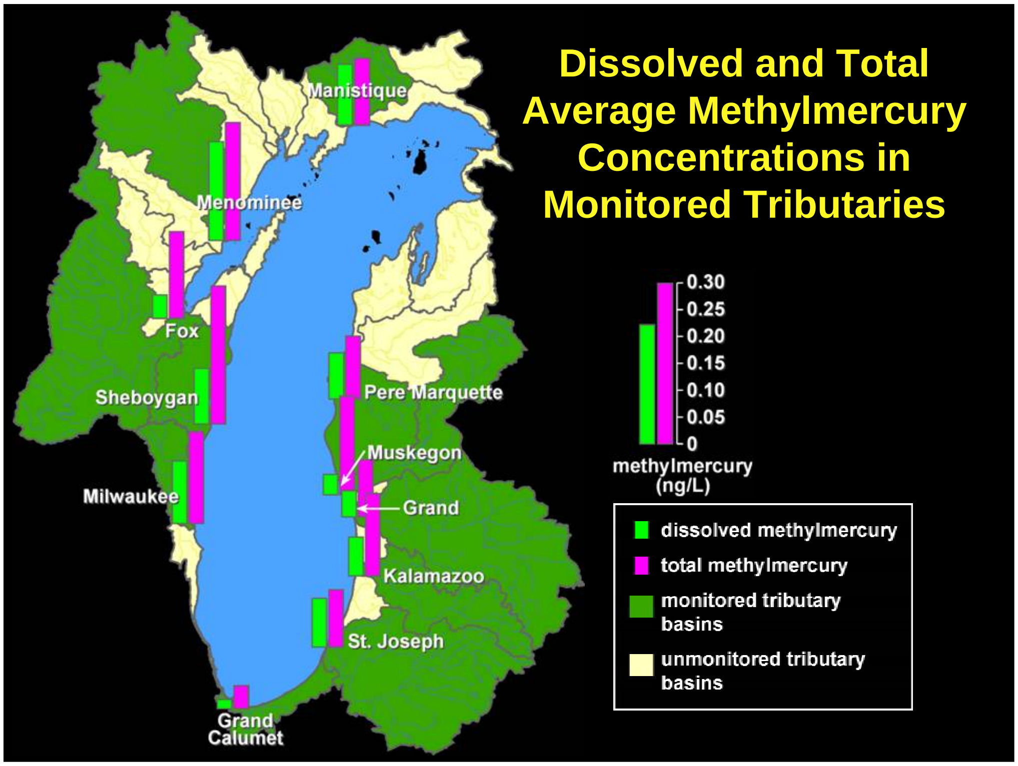
This graphic shows predicted atmospheric mercury deposition for 2001 from EPA's air model called CMAQ (Community Mesoscale Air Quality Model). Note the higher predicted deposition fluxes in the southern part of the Lake Michigan basin compared to the rest of the U.S.



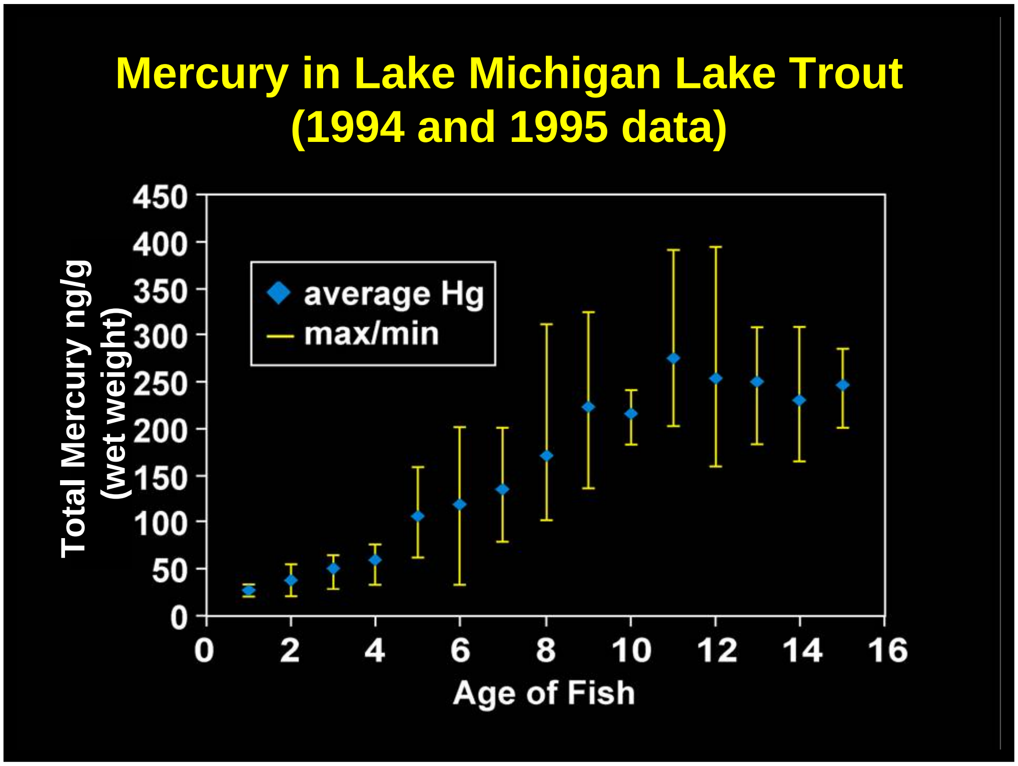
The mercury associated with atmospheric dry deposition is shown here. Note the higher fluxes in the southern part of the lake. Mercury in the vapor phase and wet deposition show similar patterns.



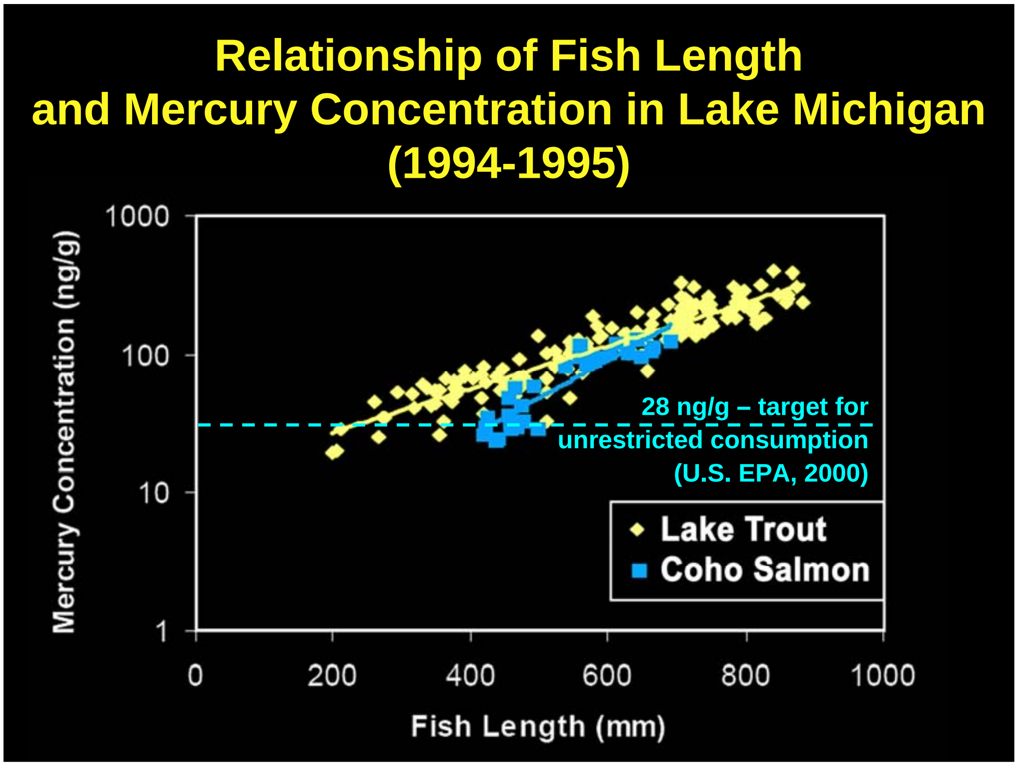
Dissolved and total mercury concentrations are shown in this graphic. Note the high concentrations in the Fox River and some rivers in the southern part of the lake.



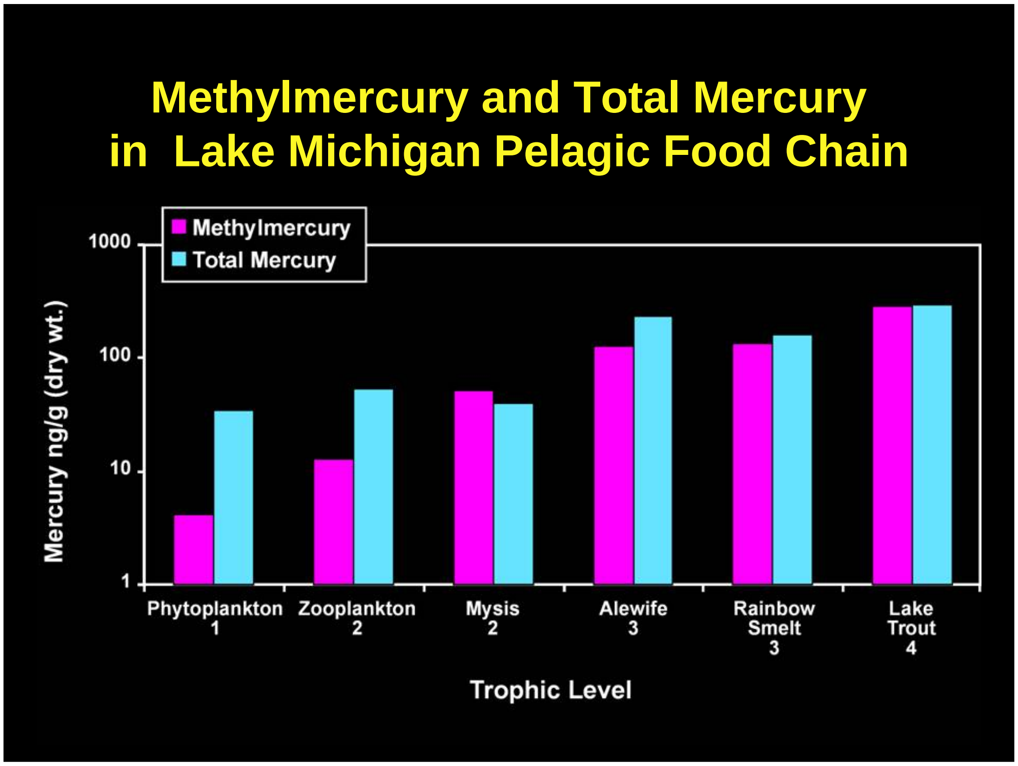
Relative to the other rivers, the Grand Calumet is low in methylmercury concentrations. Wetlands are known to convert mercury to the methyl form, and that may explain why some of the sites (Menominee, Manistique, Pere Marquette, etc.) show methylmercury concentrations that are not much different from the other sites; whereas, the total mercury from these rivers was much lower compared to the other rivers.



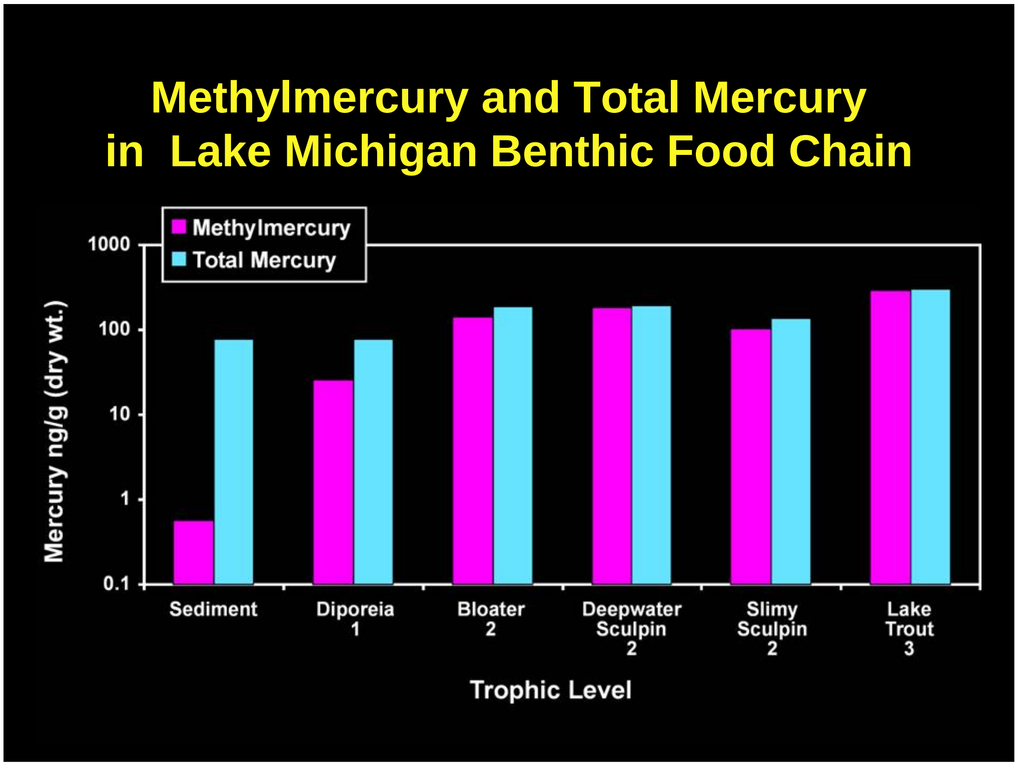
Note the increasing mercury concentration with fish age. The maximum concentration seems to be reached somewhere around age eleven.



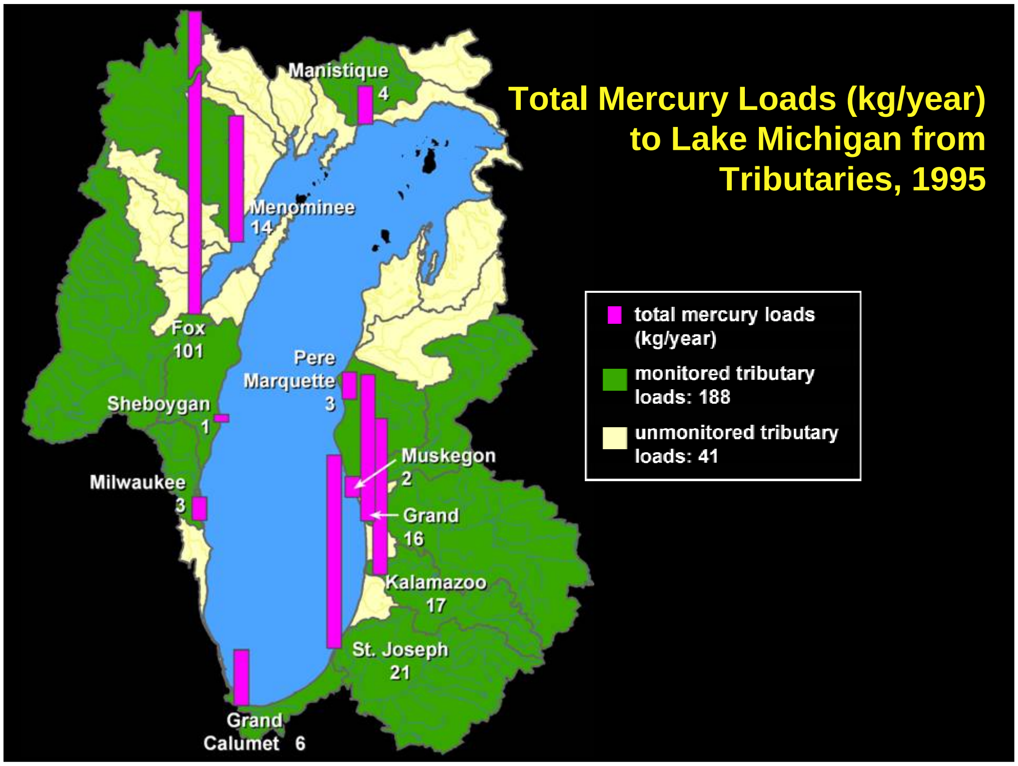
LMMBP project data are shown here for lake trout and coho salmon. However, only a few of the younger lake trout and coho salmon composites were below EPA's criteria for unrestricted consumption at 28 ng/g.



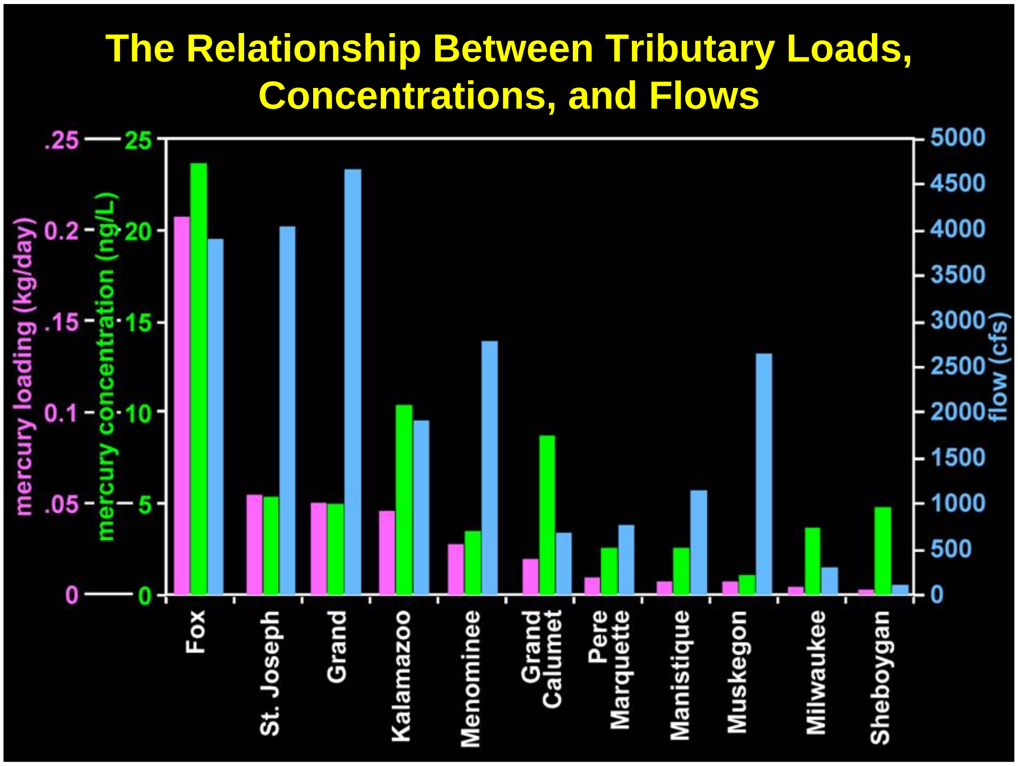
This graphic depicts the biomagnification of mercury up the pelagic food chain. Note that the percentage of methylmercury that makes up the total mercury increases as you migrate from the lower trophic levels to the higher levels. For example, methylmercury makes up less than half of the total mercury for phytoplankton, but for lake trout, all of the mercury is methylmercury. Methylmercury is more easily transferred up the food chain than ionic mercury. Therefore, looking at just the methymercury biomagnification, a pattern of trophic level increases is more easily seen.



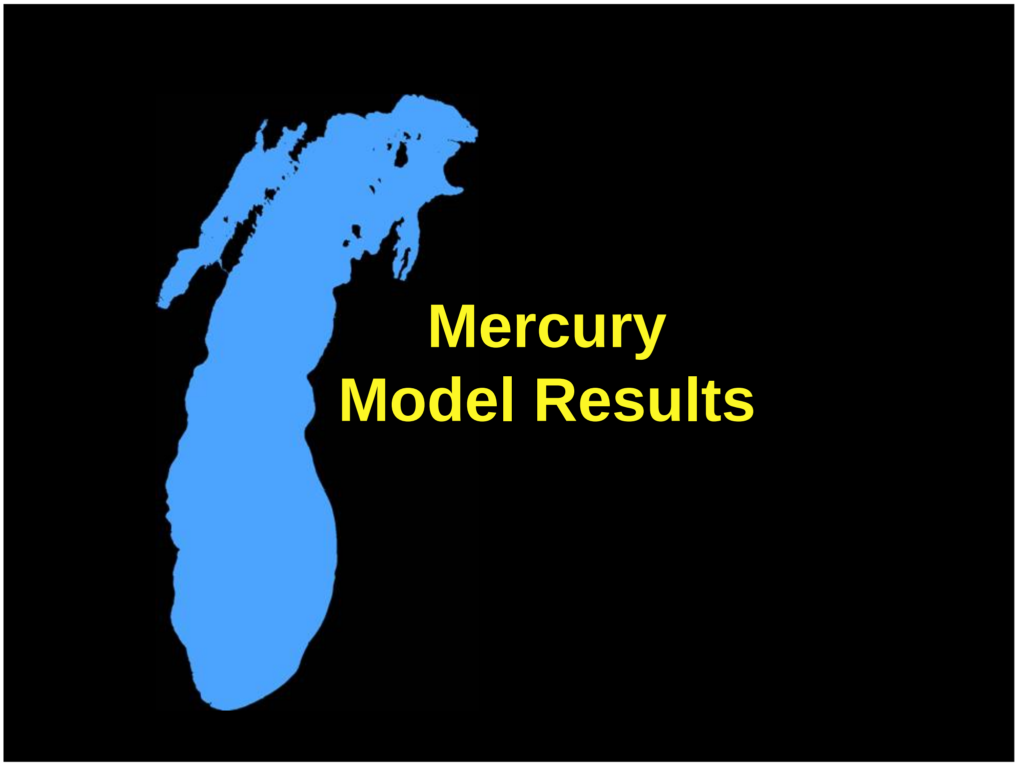
In a similar manner, this graphic shows biomagnification through the benthic food chain.



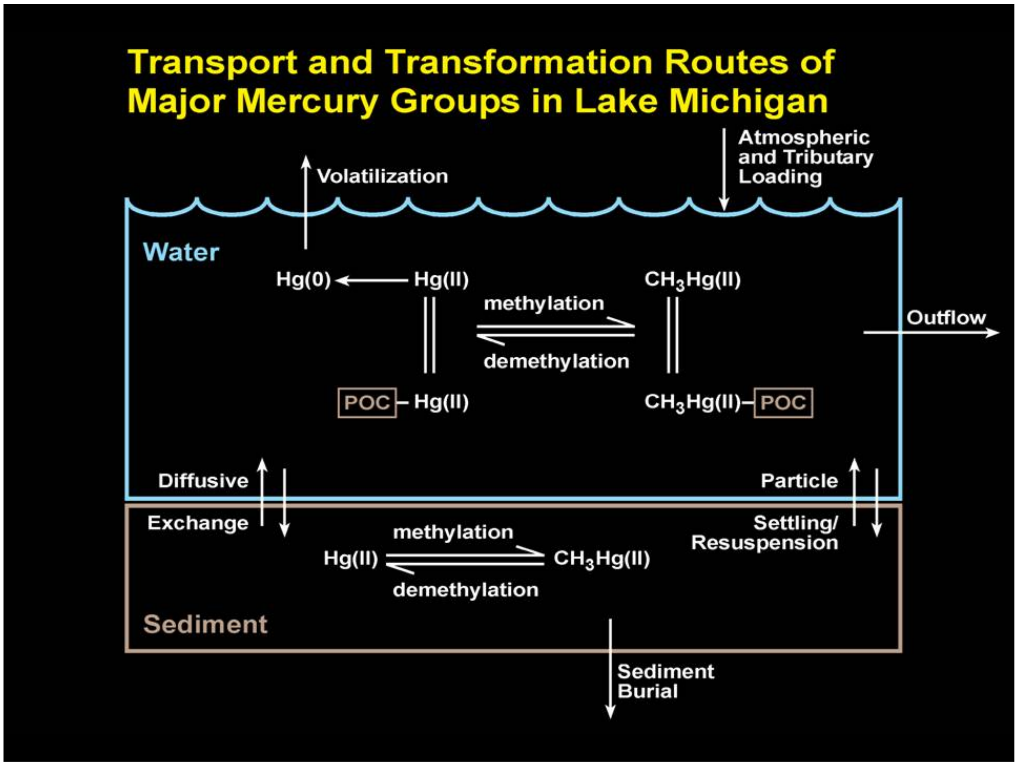
Most of the mercury loading is from the Fox R. The next highest loadings are found in southwestern Michigan.



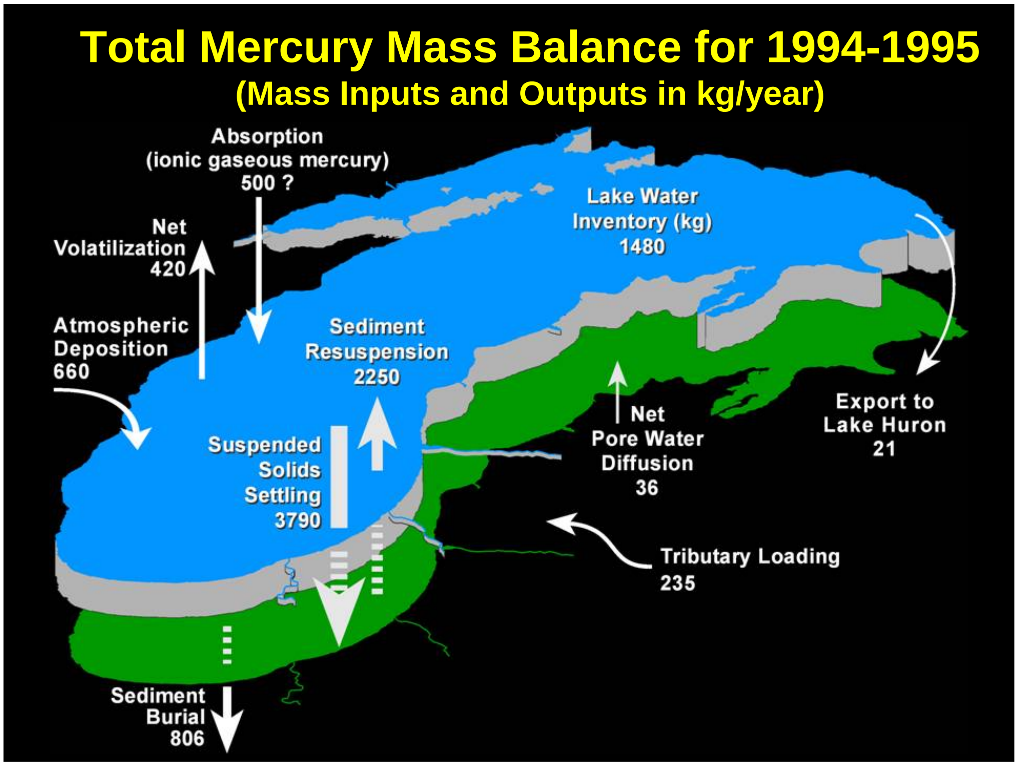
This graphic shows a comparison of mercury loadings in the tributaries relative to mercury concentrations and flows in those same rivers. The pink bars represent loadings and are ordered from a high at the Fox R. to a low at Sheboygan R. So, in comparing tributary load impact to the whole lake model, the Fox loading will have the highest impact. However, if one were to reorder the sequence to demonstrate exposure potential to aquatic life in these rivers, the Fox would still be the highest, but would be followed by the Kalamazoo River as second, and so on.



The mercury model is a screening level type of model used to gain an initial insight into some of the processes that control transport and fate. The lake model has one water segment and one sediment segment.



These are the processes that were modeled in the level 1 model. Total mercury in the system is modeled as both ionic and organic. POC is particulate organic carbon. Methylation/demethylation are modeled in both the water column and sediment. We found that assuming a net methylation/demethylation of zero in both the water column and sediment yielded model results that compared well with observations of mercury in the water column and sediment. The model required no calibration.



This is a schematic showing the total mercury mass budget in the lake. Note that atmospheric deposition is the highest input, followed by tributary loadings. The highest loss is via sediment burial, followed by volatilization out of the lake. At the time the model was constructed and run, absorption of ionic gaseous mercury was not thought to be significant and was therefore excluded. However, this process is now considered important and an estimate of that mass load is shown here. Future modeling runs will include ionic mercury absorption.

Please Note: This graphic contains provisional information and data which are subject to further evaluation and revision.

Summary

The major source of mercury to the lake is 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 mercury settling out of the water is being recycled back into the system.

The model suggests that methylmercury in the lake comes from atmospheric and watershed sources.

Next Steps

Advance the modeling effort to the higher resolution LM2 and LM3 frameworks. Include ionic gaseous mercury absorption.

Develop a food chain model.

Prepare an EPA modeling project report.

Publish results in peer reviewed journals.