Post-Audit of Lake Michigan Lake Trout
PCB Forecasts

Lake Michigan Mass Balance Study

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Lake Michigan Mass Balance Study: Cooperators

**Federal**
USEPA: GLNPO, ORD, OAR, OW, Regions 2 and 5
USGS: Middleton, Madison, Ann Arbor; NOAA-GLERL
USFWS: Green Bay; USDOE; Environment Canada

**State**
ILDNR, INDEM, MIDEQ, MDNR, WIDNR,
WI State Lab of Hygiene, Illinois Water Survey

**Academic**
Clarkson Univ; Indiana Univ; Rutgers Univ; Univ. Iowa;
Univ Maryland; Univ Michigan; Univ Minnesota;
Univ Wisconsin
Lake Michigan Mass Balance

• Identified relative pollutant loads, predict the benefits associated with reducing loads, and establish baselines.
• 1994 – 2000 (focus on 1994 and 1995 sample collection)
• 4 Target compounds
  – PCB, atrazine, trans-nonachlor, and mercury
• Over 2,00,000 data points
Lake Michigan Sampling Design

- + atmospheric monitoring stations
- ◆ sediment samples
- ● water survey stations
- ♀ tributary monitoring stations
- ⍺ unmonitored tributary basins
- ♠ monitored tributary basins
- ⭕ biota survey boxes
Lake Michigan Mass Balance Modeling Framework
PCB Mass Balance (kg/yr) for 1994-1995

- Volatilization: 3439 kg/yr
- Gas absorption: 1507 kg/yr
- Atmospheric deposition: 980 kg/yr
- Chicago River export: 8 kg/yr
- Resuspension: 1393 kg/yr
- Settling: 1136 kg/yr
- Sediment burial: 1284 kg/yr
- Green Bay export: 128 kg/yr
- Diffusion: 154 kg/yr
- Input from Lake Huron: 4 kg/yr
- Export to Lake Huron: 12 kg/yr

PCB Inventory - kg
- Water column: 1216 kg
- Active sediment: 13,085 kg
  (0 - 4 cm interval)
Total PCB Trends in Lake Michigan Media

Year

Lake trout (ppm) and water (ng/L)

Air - gas phase (pg/m²)

Sediment (ng/g) and herring gull eggs (ppm)
Average PCB Tributary Loads

Monitored tributary loads: 347 kg/year
Unmonitored tributary loads: 31 kg/year
# A Protocol for Mercury-based Fish Consumption Advice

An addendum to the 1993 “Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory”

May 2007

<table>
<thead>
<tr>
<th>Consumption Advice Groups</th>
<th>Consumption Advice Concentration of PCBs (ppm)</th>
<th>Concentration of Hg (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted Consumption</td>
<td>0 – 0.05</td>
<td>0 &lt;= 0.05</td>
</tr>
<tr>
<td>2 meals/ week</td>
<td></td>
<td>&gt; 0.05 &lt;= 0.11</td>
</tr>
<tr>
<td>1 meal/ week</td>
<td>0.06 – 0.2</td>
<td>&gt;0.11 &lt;= 0.22</td>
</tr>
<tr>
<td>1 meal/ month</td>
<td>0.21 – 1.0</td>
<td>&gt;.22 &lt;= 0.95</td>
</tr>
<tr>
<td>6 meals/ year</td>
<td>1.1 – 1.9</td>
<td></td>
</tr>
<tr>
<td>Do not eat</td>
<td>&gt;1.9</td>
<td>&gt;0.95</td>
</tr>
</tbody>
</table>

* Women of childbearing age and children under 15
Predator-Prey Feeding Interactions for Age 5.5 Lake Trout at Saugatuck

Lake Trout Age 5

- 7% Alewife Age 2
- 15% Alewife Age 4
- 14% Alewife Age 7
- 5% Rainbow Smelt Age 2
- 10% Rainbow Smelt Age 3
- 31% Bloater Age 4
- 8% Slimy Sculpin Age 3
- 10% Deepwater Sculpin Age 2

- 60% Diporeia
- 25% Mysis
- 15% Zooplankton

sediment organic carbon
Phytoplankton
Phytoplankton
Total PCBs in Lake Trout Food Web (1994-1995)

Total PCBs in Lake Trout Age Classes (1994-1995)
Example Fish Mass Balance

Rate of Concentration Change = uptake from water + uptake from prey − elimination − growth

\[ \frac{dC_f}{dt} = F_w + F_p - F_e - F_g \]
PCB Model Forecasts for Age 5.5 Whole Lake Michigan Lake Trout

<table>
<thead>
<tr>
<th>Year</th>
<th>GLNPO data</th>
<th>LMMB data</th>
<th>Constant Conditions – 1994-95 loads</th>
<th>Predicted Recovery</th>
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<tbody>
<tr>
<td>1990</td>
<td>0</td>
<td>0</td>
<td>0.16 ppm</td>
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</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>2</td>
<td>0.16 ppm</td>
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</tr>
<tr>
<td>2010</td>
<td>3</td>
<td>3</td>
<td>0.16 ppm</td>
<td>0.16 ppm</td>
</tr>
<tr>
<td>2020</td>
<td>4</td>
<td>4</td>
<td>0.16 ppm</td>
<td>0.16 ppm</td>
</tr>
<tr>
<td>2030</td>
<td>2.5</td>
<td>2.5</td>
<td>0.16 ppm</td>
<td>0.16 ppm</td>
</tr>
<tr>
<td>2040</td>
<td>1.5</td>
<td>1.5</td>
<td>0.16 ppm</td>
<td>0.16 ppm</td>
</tr>
<tr>
<td>2050</td>
<td>1</td>
<td>1</td>
<td>0.16 ppm</td>
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</tr>
</tbody>
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- EPA Wildlife Protection: 0.16 ppm
- Fish Consumption Protocol: 0.05 ppm (fillet), 0.075 ppm (whole)
PCB Forecasts and Post-Audit for Age 5.5 Lake Michigan Lake Trout

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- **EPA Wildlife Protection**: 0.16 ppm
- **Fish Consumption Protocol**: 0.05 ppm (fillet), 0.075 ppm (whole)
- **Constant Conditions – 1994-95 loads**
- **Predicted Recovery**: 2035

**Post-Audit Data**
- Sturgeon Bay
- Saugatuck

**Graph Details**
- GLNPO data, LMNB data, Post-Audit Data, Predicted Recovery

**Graph Elements**
- Total PCB (µg/g) axis
- Year axis
- Data points and trend lines for different data sets and protocols.
Environmental Variability and Model Uncertainty

- Water Levels and Temperature
- Food Web Alterations
  - Food Availability; Diet Changes
  - Growth Kinetics, Nutrition, and Age/Length Relationships
  - Whole versus Fillet Relationship
  - Contaminant flow and concentration
- Load Decline/Pace of Remedial Actions
Estimated Lake-Wide Biomass of Prey Fishes in Lake Michigan, 1973-2013 (a); Species Composition in 2013 (b). Madenjian et al. 2014, USGS, GLFC Lake Michigan Committee
Diet Composition (%) of Lake Trout at Saugatuck 1994-95 versus 2005

From Brey, M.K. 2006
Lake Michigan Lake Trout
Age versus Length (2004-2013)
PCB Forecasts and Post-Audit for Age 5.5 Whole Lake Michigan Lake Trout

With Comparison to Fillets (●)

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Post-Audit Data

- Sturgeon Bay
- Saugatuck

Constant Conditions – 1994-95 loads

Predicted Recovery

EPA Wildlife Protection
- 0.16 ppm

Fish Consumption Protocol
- 0.05 ppm (fillet)
- 0.075 ppm (whole)

GLNPO data
LMMB data

0.05 ppm (fillet)
0.075 ppm (whole)
Major Findings

- Forecasted PCB concentrations in Lake Trout suggests Unlimited Consumption as early as 2035 for Age 5-6 Lake Michigan Lake Trout
- The approximate 20-year Post Audit indicates reasonable agreement between observed and forecasted concentrations
- PCB trends indicate that concentrations are declining in all media
- Atmospheric Deposition is the major external source of PCBs to the lake followed by Tributaries
- Major fluxes of PCBs move in and out of the sediments through dynamic interaction
- Food web changes observed may be a future challenge