PCBs in Upper Hudson River Resident Fish Species: Importance of Biological Parameters and Sediment Scale

Jay Field ¹ and John Kern ²

¹ NOAA, Office of Response and Restoration, Seattle, Washington
² Kern Statistical Services, Inc., Sauk Rapids, Minnesota

SETAC 2009
New Orleans, Louisiana
November 22, 2009
Acknowledgements

• Funding provided by the Hudson River Natural Resource Trustees
• Fish data provided by NYSDEC (Mike Kane) and General Electric and EPA
• Sediment data provided by GE and EPA
• Ron Sloan, NY State Dept. Environmental Conservation, retired
• George Graettinger, NOAA, Office of Response and Restoration, GIS Coordinator
Disclaimer

• The conclusions and opinions presented here are those of the authors and do not represent the official position of any of the funding agencies, the Hudson River Trustees, or the United States.
Objectives

• Evaluate the importance of biological factors (lipid, size, gender) and sediment factors (spatial scale of exposure, TOC) in bioaccumulation of PCBs in resident fish species in the Upper Hudson River
Upper Hudson River
Data

- **Fish (2003-7)**
  - 6 species groups collected from multiple discrete locations by NYSDEC and GE as part of annual baseline monitoring program

- **Sediment (2002-7)**
  - ~9000 cores collected during remedial design sampling over systematic grid
  - 7400+ samples from top 2 inches with total PCB and TOC measurements
Fish Species/Species Groups

Number of Samples

- Black bass (SF) 395
- Brown bullhead (SF) 371
- Yellow perch (SF) 418
- Sunfish (SF) 137
- Pumpkinseed 1+ (WH) 342
- Forage fish (WH) 192

SF: Standard Fillet
WH: Whole Body
Average Sediment and Water Total PCBs

Total PCBs in Sediment
(Top 2 inches)

Section 1
Section 2
Section 3a
Section 3b
Section 3c

Total PCBs (mg/kg)

Summer Total PCBs in Water
May – September 2004-7

Bakers Falls
Rogers Island
Section 1
Section 2
Section 3a
Section 3b
Section 3c

Total PCBs (ng/L)
BSAFs by River Reach

Black bass (fillet) and Bullhead (fillet)
Statistical Approach

- Develop empirical regression functions to evaluate selected fish and sediment factors that may affect bioaccumulation
- Akaike Information Criterion (AIC) was used to rank competing functions and identify the least complex function that adequately explains important features of the data
Generalization of the BSAF
Bioaccumulation Function

\[
BSAF = \left( \frac{C_f}{\text{Lipid}^{\beta_1}} \right) \left( \frac{C_s^{\beta_2}}{\text{TOC}^{-\beta_3}} \right) \quad \Leftrightarrow \quad \beta_1 = \beta_2 = -\beta_3 = 1.0
\]

\[
\log(C_f) = \log(\text{BSAF}) + \beta_1 \log(\text{Lipid}) + \beta_2 \log(C_s) + \beta_3 \log(\text{TOC})
+ (\text{Other Factors})
\]

- Functions were consistent with the Biota-Sediment Accumulation Factor (BSAF) model and include the BSAF as a special case
- Other factors can be incorporated and compared
Biological Parameters

- Fish
  - Percent lipid
  - Size (Length, Weight, Condition factor)
  - Gender
### Example Delta AIC: Bullhead

<table>
<thead>
<tr>
<th>Parameters Included</th>
<th>Number of Samples</th>
<th>Degrees of Freedom</th>
<th>Delta AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipid Length</td>
<td>371</td>
<td>368</td>
<td>0</td>
</tr>
<tr>
<td>Lipid Weight</td>
<td>371</td>
<td>368</td>
<td>1.3</td>
</tr>
<tr>
<td>Lipid Length ConditionFactor</td>
<td>371</td>
<td>367</td>
<td>1.8</td>
</tr>
<tr>
<td>Lipid</td>
<td>371</td>
<td>369</td>
<td>20.4</td>
</tr>
<tr>
<td>Lipid ConditionFactor</td>
<td>371</td>
<td>368</td>
<td>22.4</td>
</tr>
</tbody>
</table>
# Selected Biological Parameters

<table>
<thead>
<tr>
<th>Species Group</th>
<th>Number of Samples</th>
<th>Lipid</th>
<th>Length</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bass (SF)</td>
<td>395</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bullhead (SF)</td>
<td>371</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Perch (SF)</td>
<td>418</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunfish (SF)</td>
<td>141</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumpkinseed (WH)</td>
<td>345</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage Fish (WH)</td>
<td>193</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SF: Standard fillet  
WH: Whole body
Sediment Parameters

- Sediment
- Total Organic Carbon (TOC)
- Average Total PCBs (DW) at different spatial scales
Reach-Wide Sediment Samples

Reach 8

Fish Sampling Location

Reach 7

Fish Sampling Location
Sediment Samples Within 100 m
Fish Habitat Area

Reach 8
Fish Collection Area

Reach 8
River Mile

Reach 8: 0.5 mi up / 0.5 mi down
Reach 8: 0.9 mi up / 0.1 mi down
## Delta AIC for Spatial Scale
### Black Bass

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Delta AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipid Length Sex RiverMile TOC</td>
<td>0</td>
</tr>
<tr>
<td>Lipid Length Sex Section TOC</td>
<td>5.9</td>
</tr>
<tr>
<td>Lipid Length Sex Reach TOC</td>
<td>6.5</td>
</tr>
<tr>
<td>Lipid Length Sex Collection_Area TOC</td>
<td>6.7</td>
</tr>
<tr>
<td>Lipid Length Sex Habitat TOC</td>
<td>9.2</td>
</tr>
<tr>
<td>Lipid Length RiverMile TOC</td>
<td>15.0</td>
</tr>
<tr>
<td>Lipid Length Collection_Area TOC</td>
<td>20.2</td>
</tr>
<tr>
<td>Lipid Length Section TOC</td>
<td>21.1</td>
</tr>
<tr>
<td>Lipid Length Reach TOC</td>
<td>21.1</td>
</tr>
<tr>
<td>Lipid Length Sex Buffer TOC</td>
<td>22.7</td>
</tr>
<tr>
<td>Lipid Length Habitat TOC</td>
<td>23.4</td>
</tr>
<tr>
<td>Lipid Length Buffer TOC</td>
<td>37.6</td>
</tr>
<tr>
<td>Lipid Length</td>
<td>45.5</td>
</tr>
</tbody>
</table>
# Selected Models

## Sediment Spatial Scale

<table>
<thead>
<tr>
<th>Species Group</th>
<th>TOC</th>
<th>River Section</th>
<th>River Reach</th>
<th>River Mile (0.9/0.1)</th>
<th>Habitat</th>
<th>Collection Area</th>
<th>Buffer (200 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Bass (SF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bullhead (SF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Perch (SF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunfish (SF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumpkinseed (WH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage Fish (WH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SF: Standard fillet  
WH: Whole body
Percent Total PCB Variation in Fish Tissue Explained by Models

Bbass | Bullhead | Sunfish | YPerch | Forage | PKSD

<table>
<thead>
<tr>
<th>Standard Fillet</th>
<th>Whole Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Lipid</td>
</tr>
<tr>
<td>8%</td>
<td>13%</td>
</tr>
<tr>
<td>26%</td>
<td>27%</td>
</tr>
<tr>
<td>10%</td>
<td>7%</td>
</tr>
</tbody>
</table>
Model Performance
Observed/Predicted: Bullhead

Reach

Observed / Predicted

Model

BSAF

0.1
1.0
10.0
10.0

9
8
7
6
5
4

4
5
6
7
8
9

0.1
Predicted Fish Tissue vs. Sediment

Sediment Total PCB (mg/kg)

Fish Tissue Total PCB (mg/kg)

- Bullhead SF
- Forage WH
- Sunfish SF
- Black Bass SF
- Yellow Perch SF
- PKSD WH

0 10 20 30 40 50

0 3 6 9 12 15

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Regression Coefficients for Lipid

$H_0 : \beta_1 = 1.0$
$H_a : \beta_1 \neq 1.0$

$BSAF = \left( \frac{C_f / f_{Lipid}^{\beta_1}}{C_s^{\beta_2} / f_{OC}^{-\beta_3}} \right) \iff \beta_1 = \beta_2 = -\beta_3 = 1.0$
Regression Coefficients for Sediment Total PCB

\[ H_0 : \beta_2 = 1.0 \]
\[ H_a : \beta_2 \neq 1.0 \]

\[
BSAF = \left( \frac{C_f \beta_1}{f_{Lipid}^{\beta_1}} \right) \left( \frac{C_s^{\beta_2} \beta_3}{f_{OC}^{-\beta_3}} \right) \iff \beta_1 = \beta_2 = -\beta_3 = 1.0
\]
Regression Coefficients for Organic Carbon

\[ BSAF = \left( \frac{C_f}{f_{Lipid}} \right)^{\beta_1} \left( \frac{C_s}{f_{OC}} \right)^{\beta_2} \left( f_{Lipid} \right)^{-\beta_3} \quad \Leftrightarrow \quad \beta_1 = \beta_2 = -\beta_3 = 1.0 \]
Summary

• The best predictors of sediment exposure area varied among the species groups, but all scales were more localized than a river reach---even for larger fish which are often assumed to integrate over a reach.

• Lipid content and sediment PCBs were the most important predictors for all species groups. Differences in accumulation by gender (bass and sunfish) and fish length (bullhead) were also important.

• Differences in biological parameter values may be large enough to affect interpretation of monitoring results.
• PCB accumulation was strongly associated with both lipid and sediment but the relationships were nonlinear
• Organic carbon was much less important in accumulation of PCBs in fish than suggested by theoretical models (BSAF)
• The regression approach accommodated nonlinearity in the accumulation relationship that might otherwise require subsetting data and estimation of separate BSAFs, which may not be possible at most sites