

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

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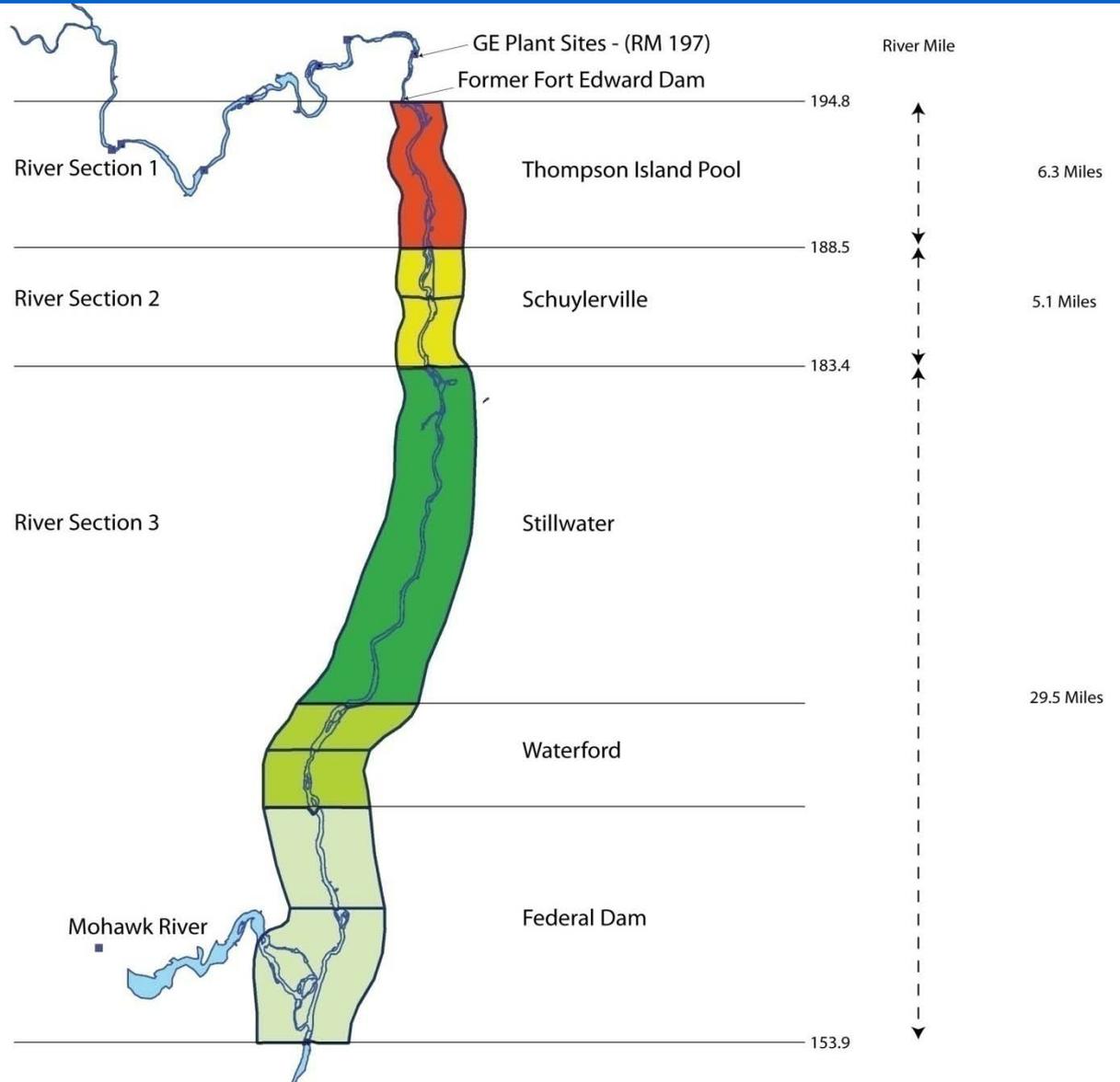
Disclaimer

- 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

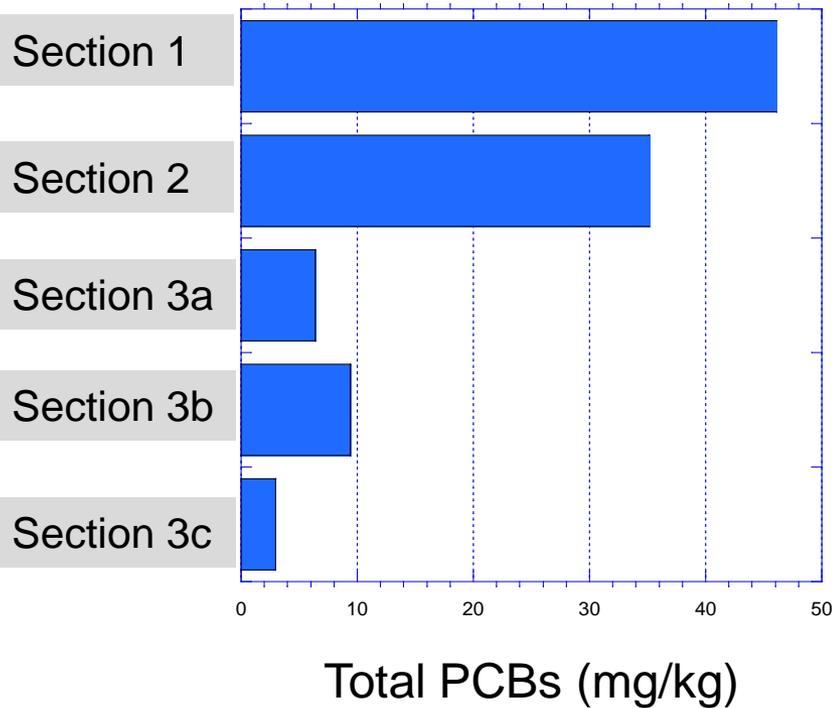
- Fish (2003-7)
 - 6 species groups collected from multiple discrete locations by NYSDEC and GE as part of annual baseline monitoring program
- Sediment (2002-7)
 - ~9000 cores collected during remedial design sampling over systematic grid
 - 7400+ samples from top 2 inches with total PCB and TOC measurements

Fish Species/Species Groups

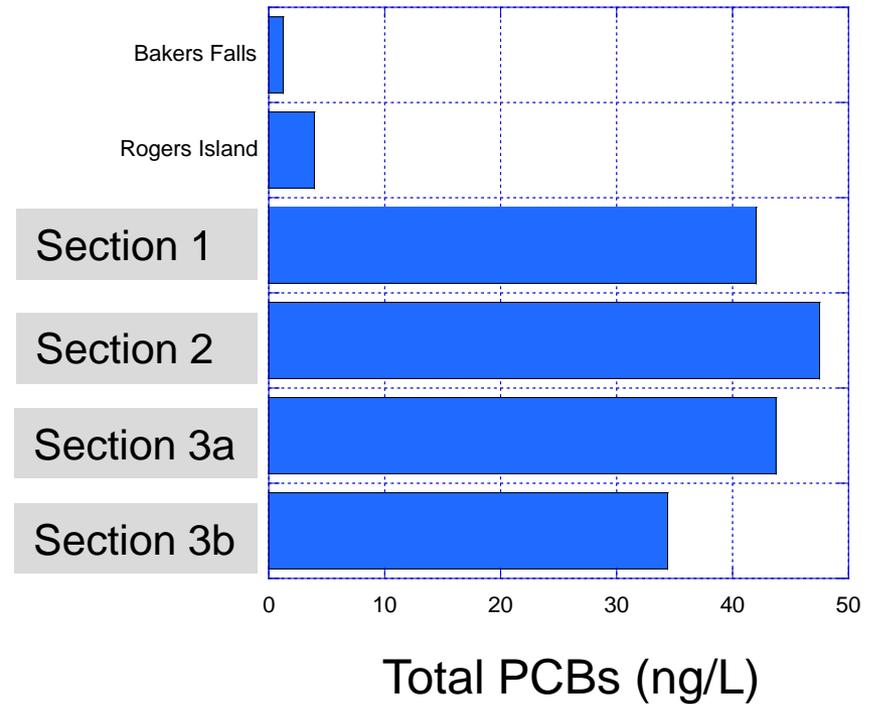
	Number of Samples
• Black bass (SF)	395
• Brown bullhead (SF)	371
• Yellow perch (SF)	418
• Sunfish (SF)	137
• Pumpkinseed 1+ (WH)	342
• Forage fish (WH)	192
• SF: Standard Fillet	
• WH: Whole Body	

Average Sediment and Water Total PCBs

Total PCBs in Sediment (Top 2 inches)



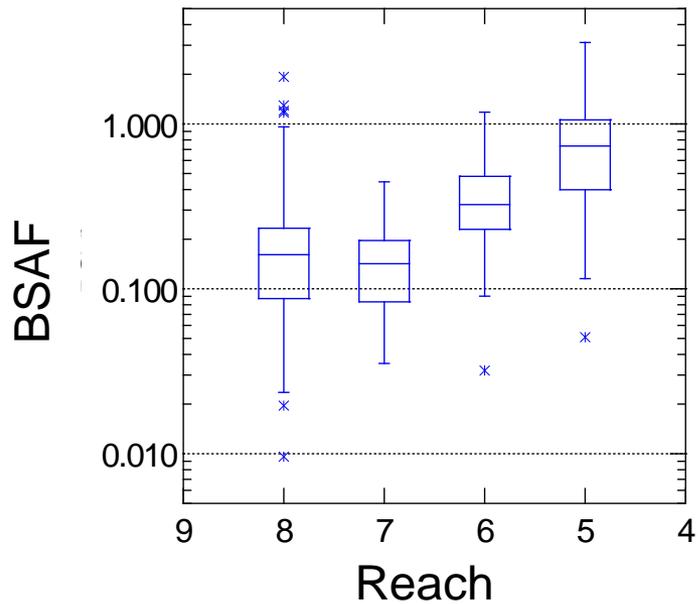
Summer Total PCBs in Water May – September 2004-7



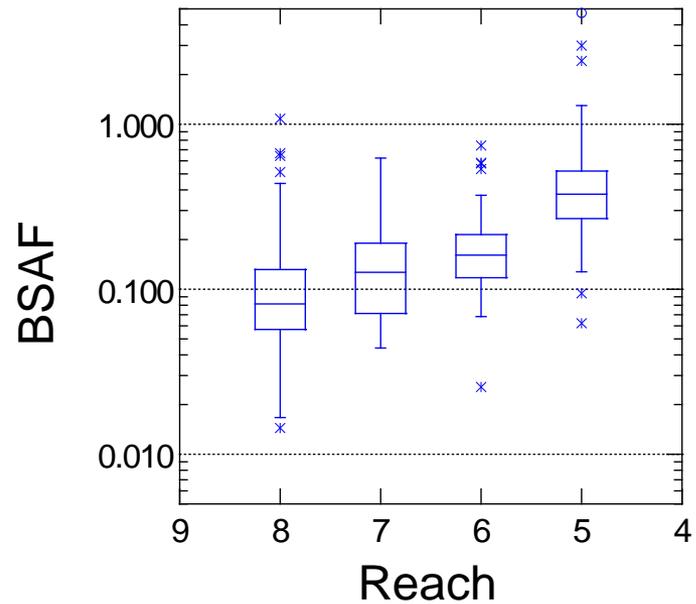
BSAFs by River Reach

Black bass (fillet) and Bullhead (fillet)

Black Bass



Bullhead



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

$$BSAF = \frac{(C_f / Lipid^{\beta_1})}{(C_s^{\beta_2} / TOC^{-\beta_3})} \Leftrightarrow \beta_1 = \beta_2 = -\beta_3 = 1.0$$

$$\begin{aligned} \text{Log}(C_f) = & \text{Log}(BSAF) + \beta_1 \text{Log}(Lipid) + \beta_2 \text{Log}(C_s) + \beta_3 \text{Log}(TOC) \\ & + (\text{Other Factors}) \end{aligned}$$

- 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

Parameters Included	Number of Samples	Degrees of Freedom	Delta AIC
Lipid Length	371	368	0
Lipid Weight	371	368	1.3
Lipid Length ConditionFactor	371	367	1.8
Lipid	371	369	20.4
Lipid ConditionFactor	371	368	22.4

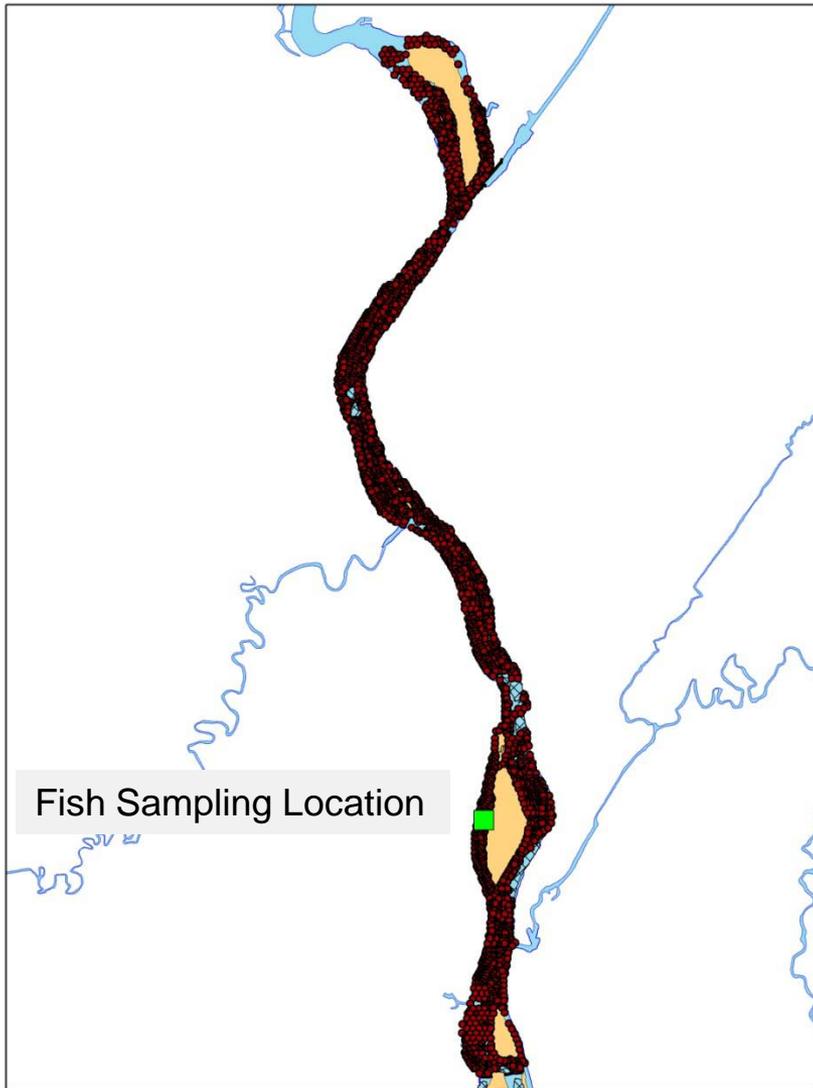
Selected Biological Parameters

Species Group	Number of Samples	Biological Parameters		
		Lipid	Length	Sex
Black Bass (SF)	395			
Bullhead (SF)	371			
Yellow Perch (SF)	418			
Sunfish (SF)	141			
Pumpkinseed (WH)	345			
Forage Fish (WH)	193			
SF: Standard fillet				
WH: Whole body				

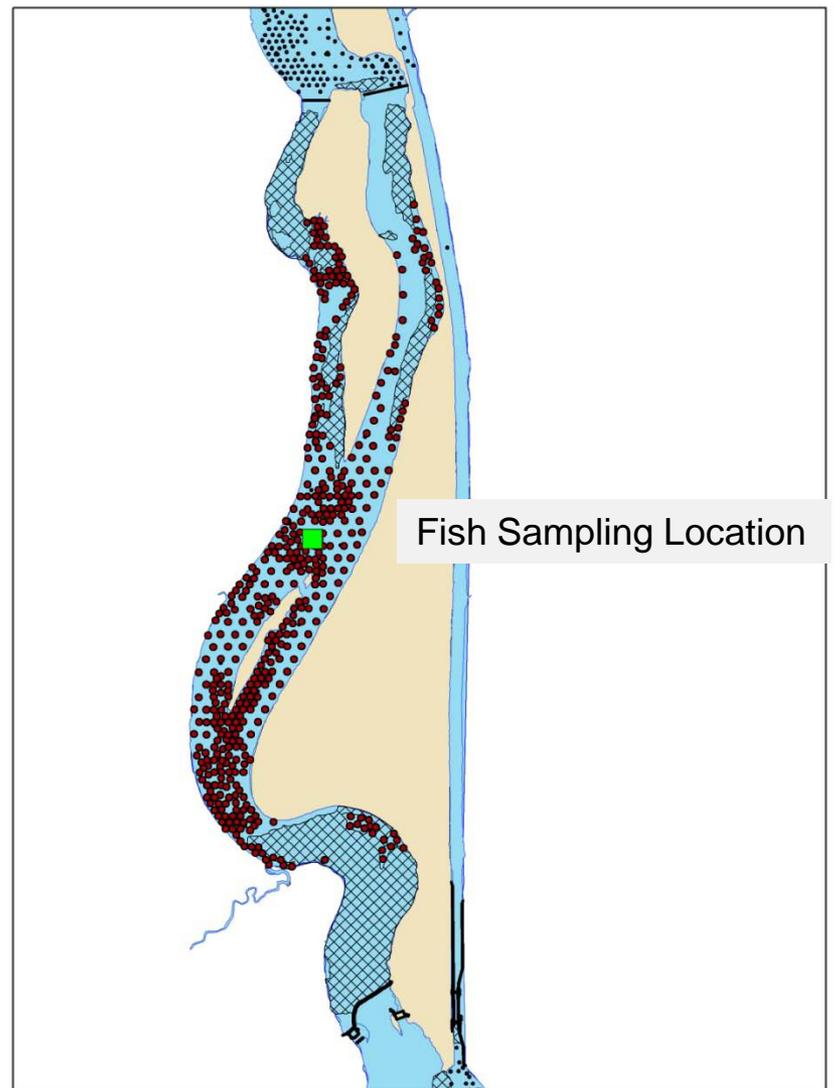
Sediment Parameters

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

Reach-Wide Sediment Samples

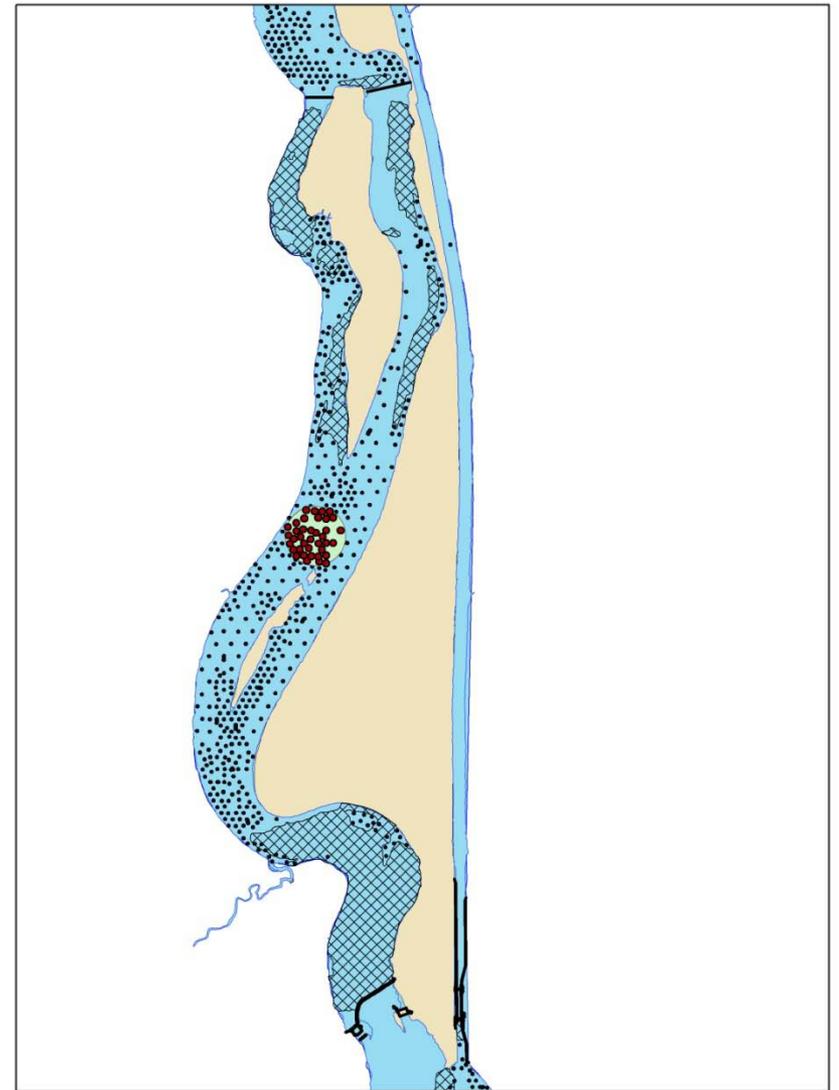
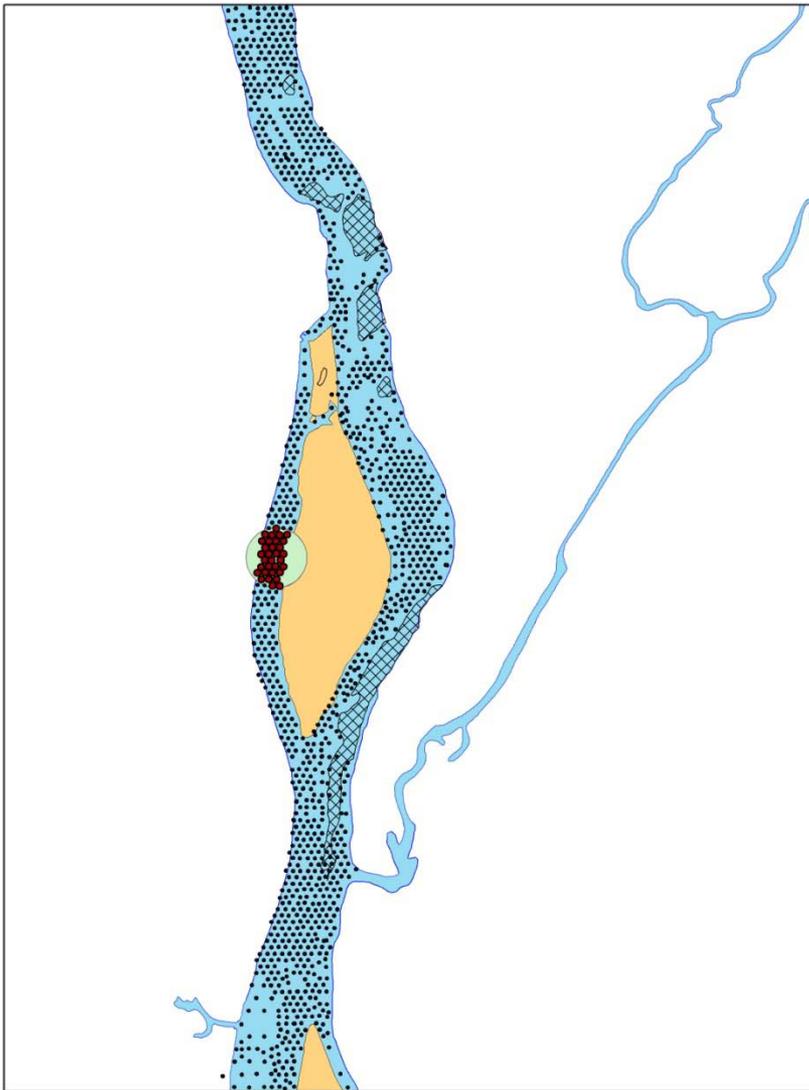


Reach 7



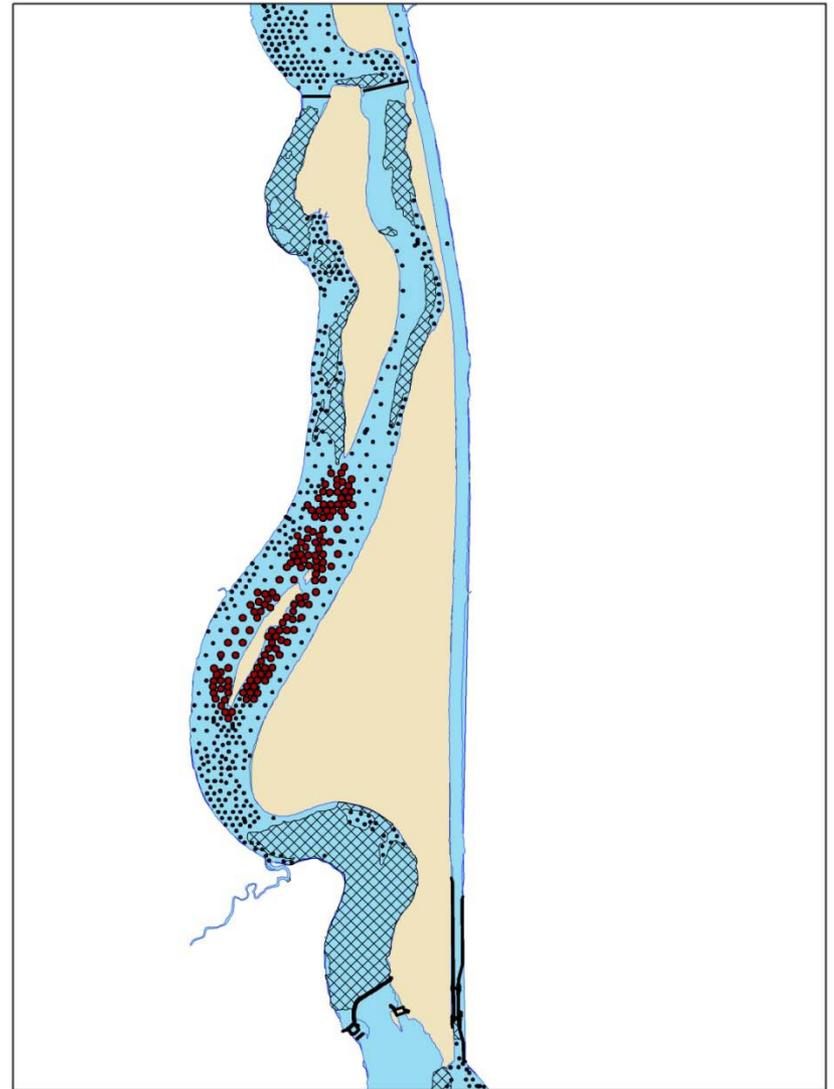
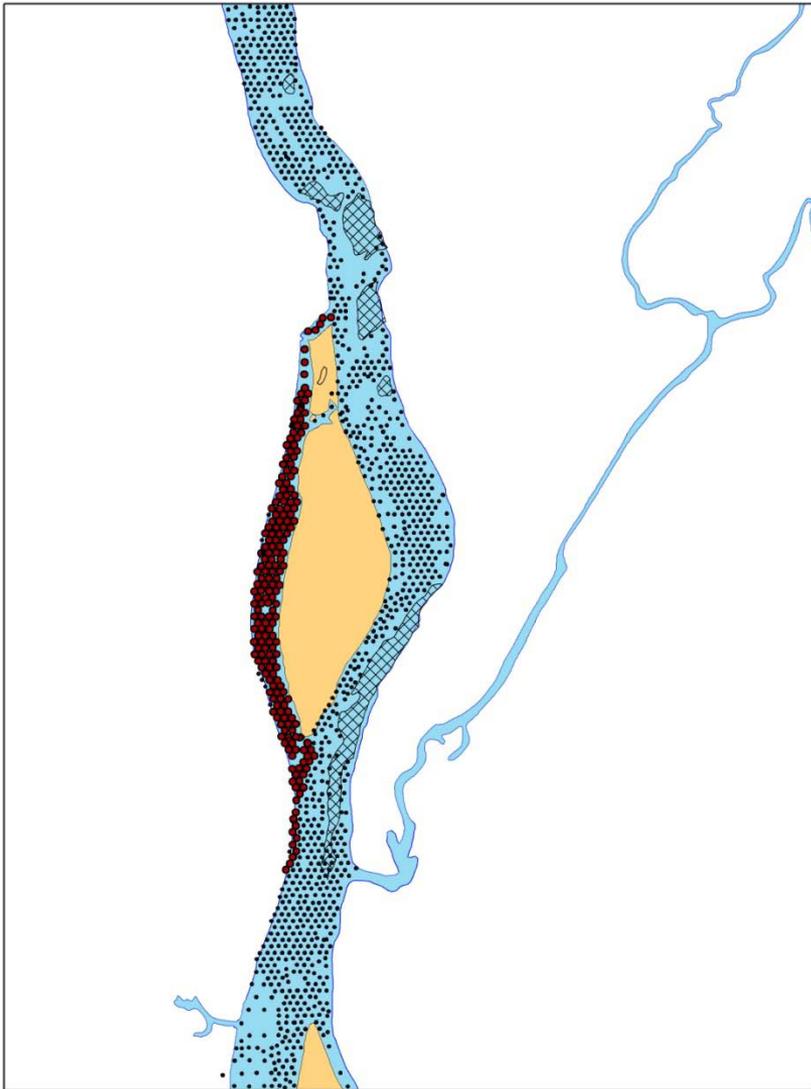
Sediment Samples Within 100 m

Reach 7



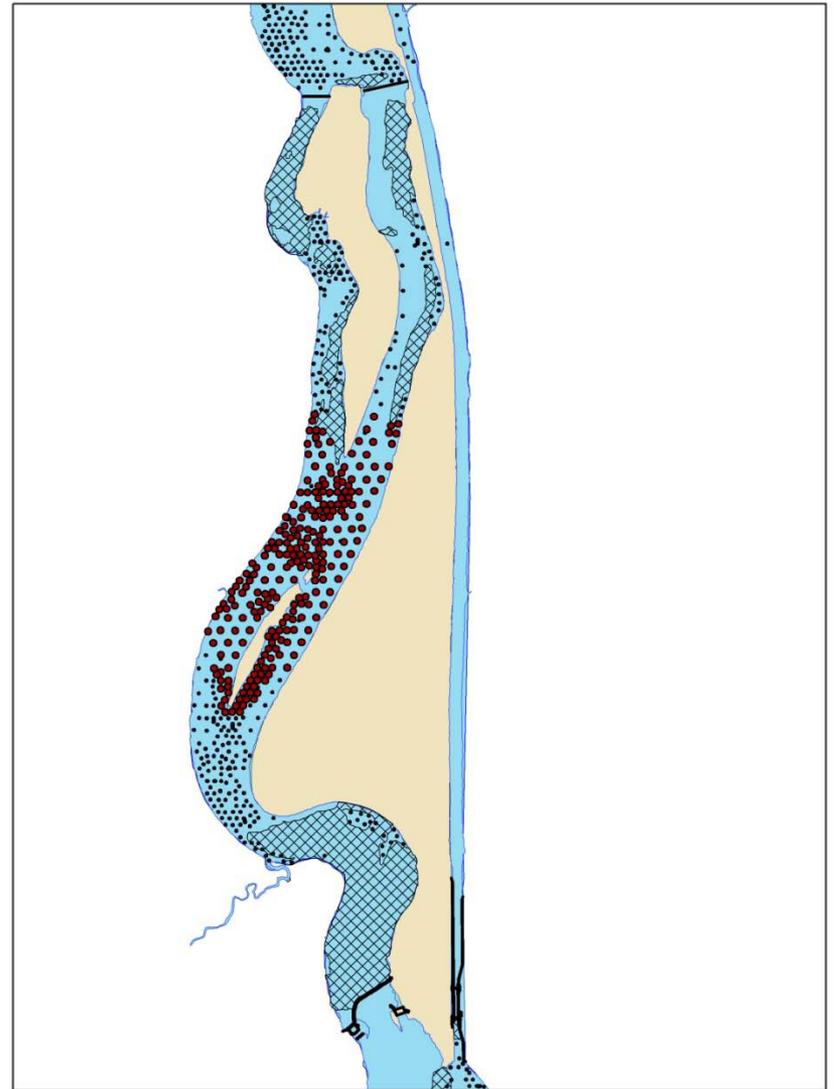
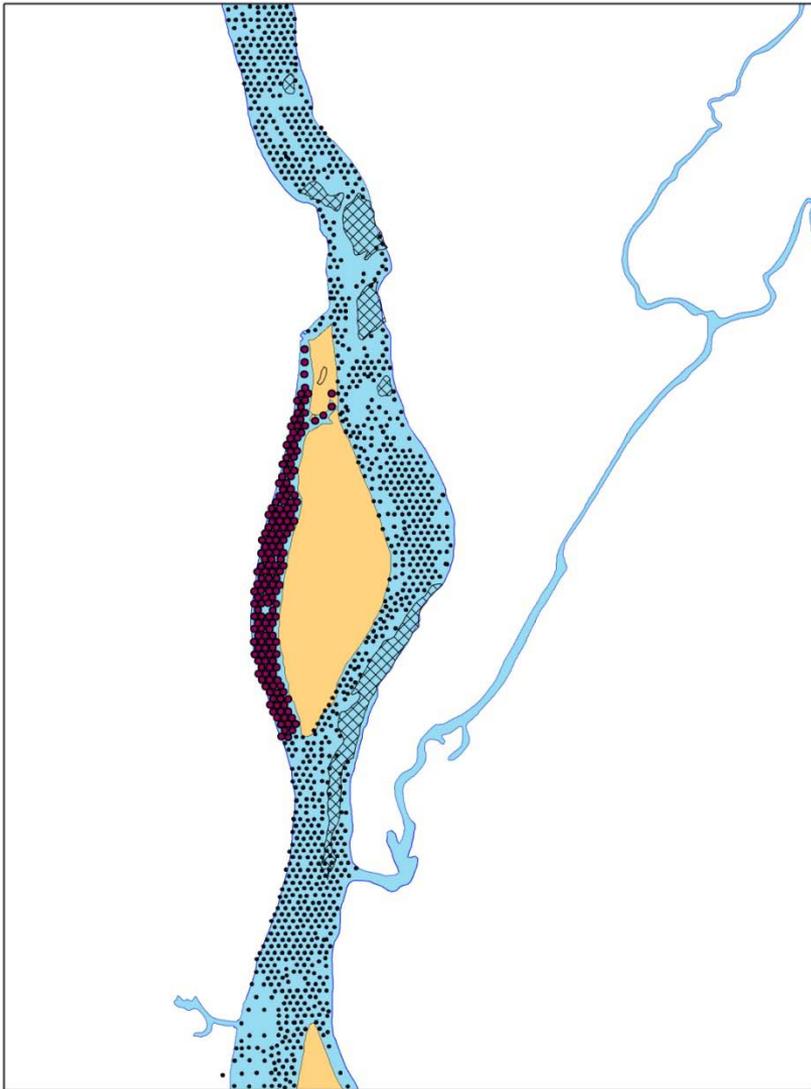
Fish Habitat Area

Reach 8

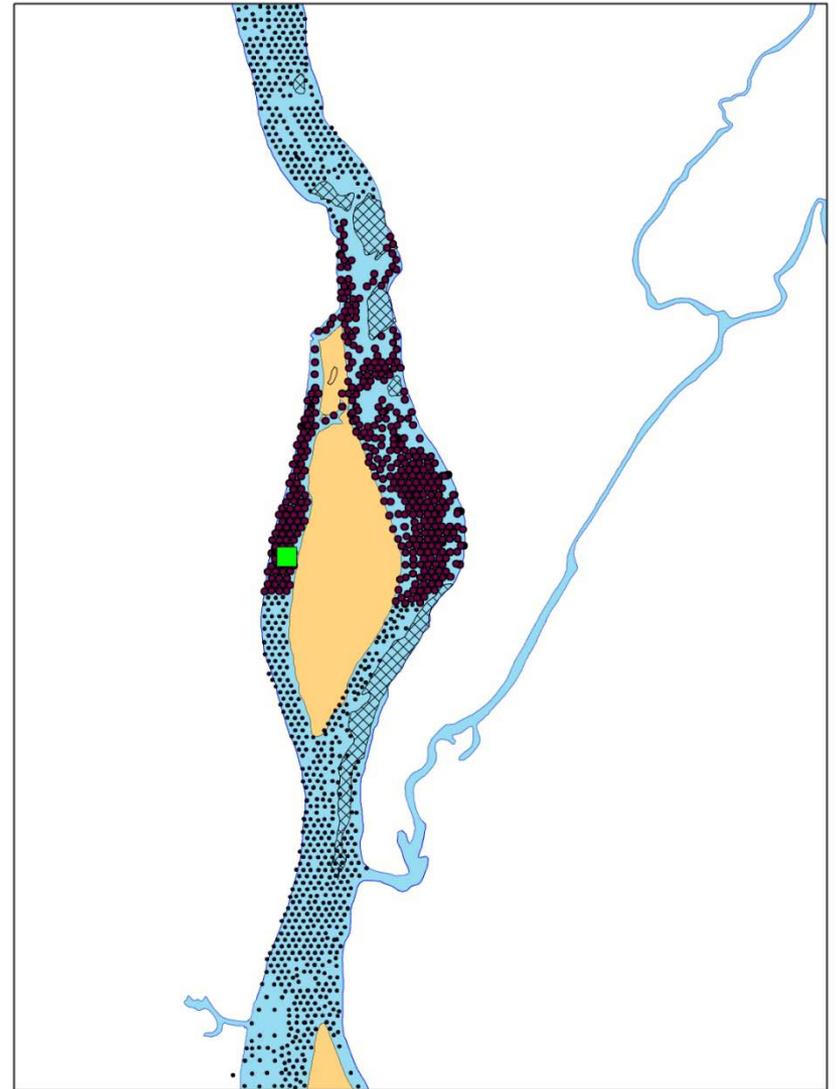
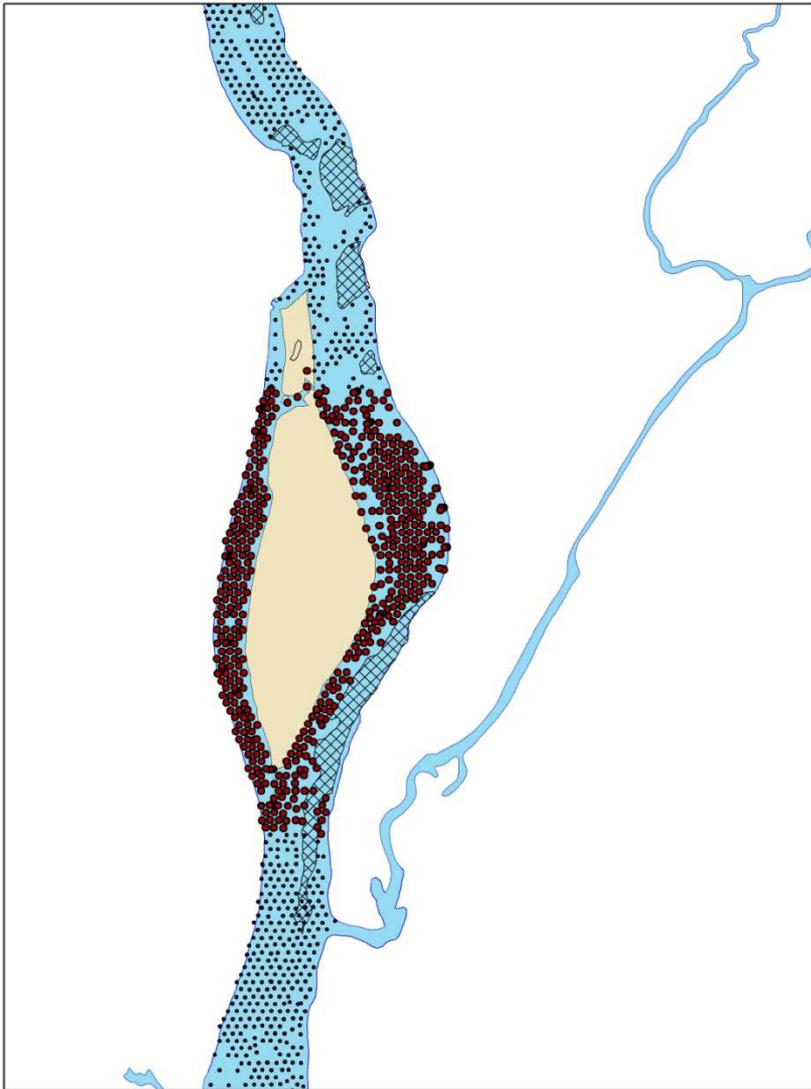


Fish Collection Area

Reach 8



River Mile



Delta AIC for Spatial Scale Black Bass

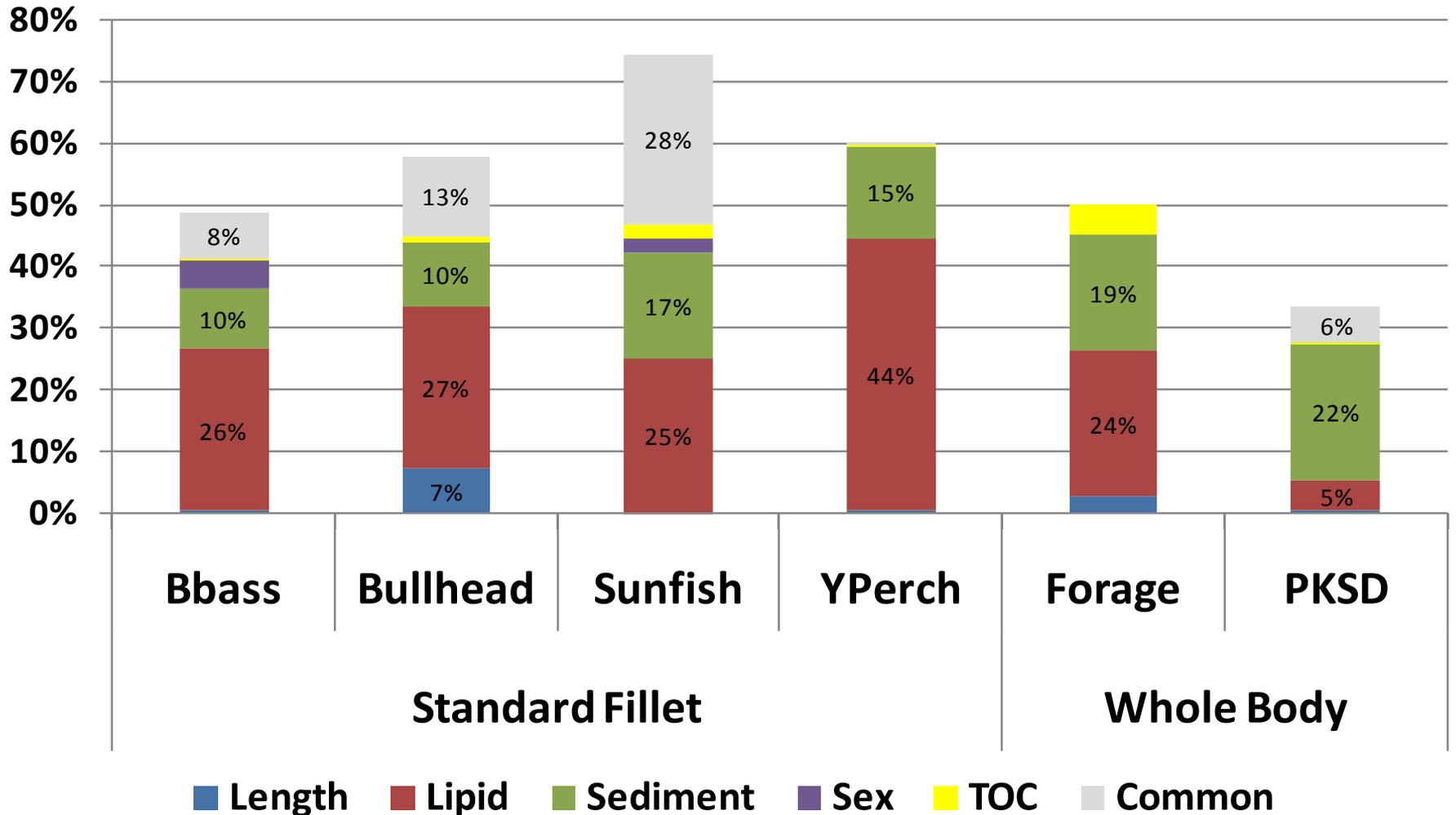
Parameters	Delta AIC
Lipid Length Sex RiverMile TOC	0
Lipid Length Sex Section TOC	5.9
Lipid Length Sex Reach TOC	6.5
Lipid Length Sex Collection_Area TOC	6.7
Lipid Length Sex Habitat TOC	9.2
Lipid Length RiverMile TOC	15.0
Lipid Length Collection_Area TOC	20.2
Lipid Length Section TOC	21.1
Lipid Length Reach TOC	21.1
Lipid Length Sex Buffer TOC	22.7
Lipid Length Habitat TOC	23.4
Lipid Length Buffer TOC	37.6
Lipid Length	45.5

Selected Models

Sediment Spatial Scale

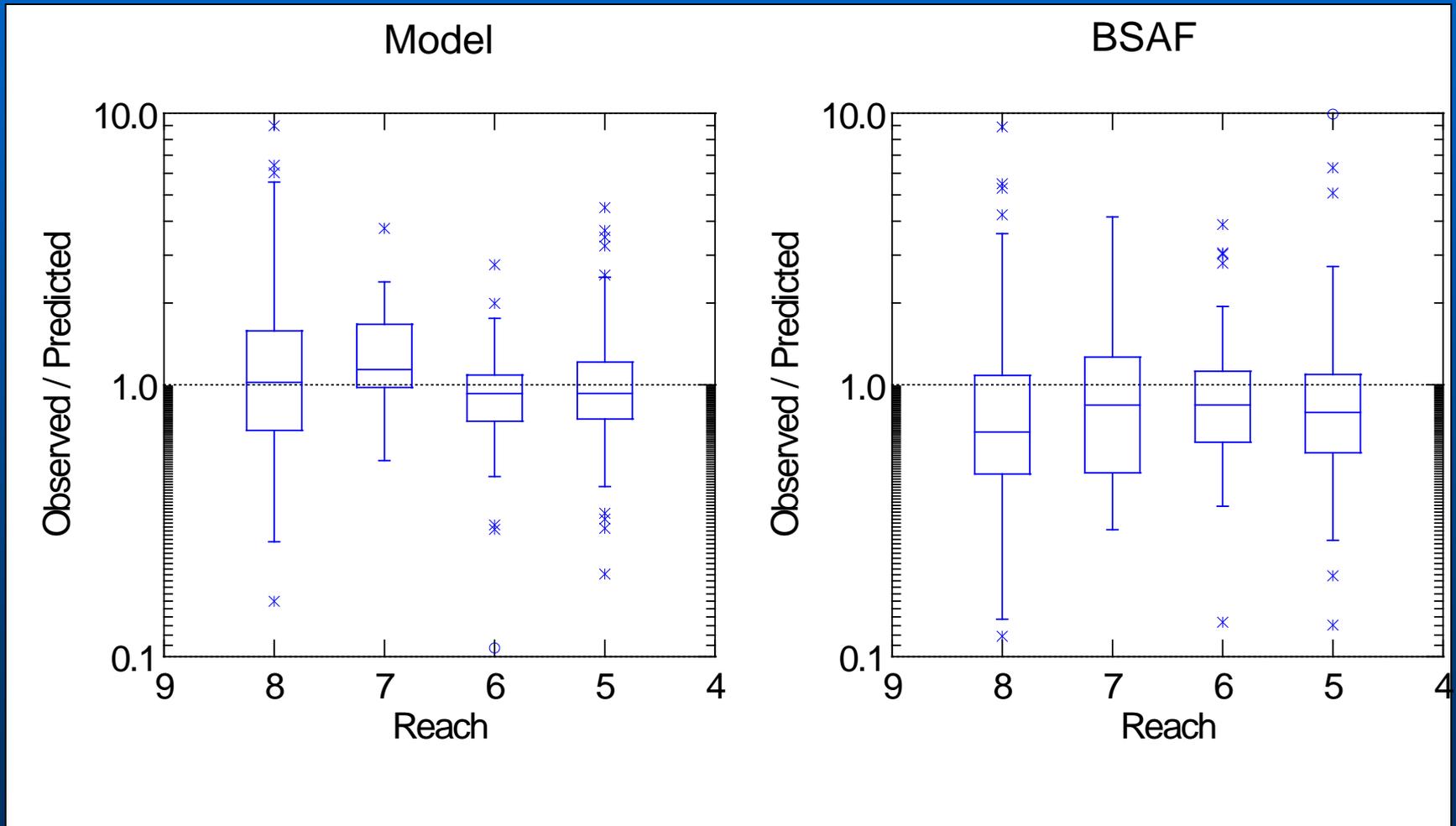
		Sediment Spatial Scale					
Species Group	TOC	River Section	River Reach	River Mile (0.9/0.1)	Habitat	Collection Area	Buffer (200 m)
Black Bass (SF)							
Bullhead (SF)							
Yellow Perch (SF)							
Sunfish (SF)							
Pumpkinseed (WH)							
Forage Fish (WH)							
SF: Standard fillet							
WH: Whole body							

Percent Total PCB Variation in Fish Tissue Explained by Models

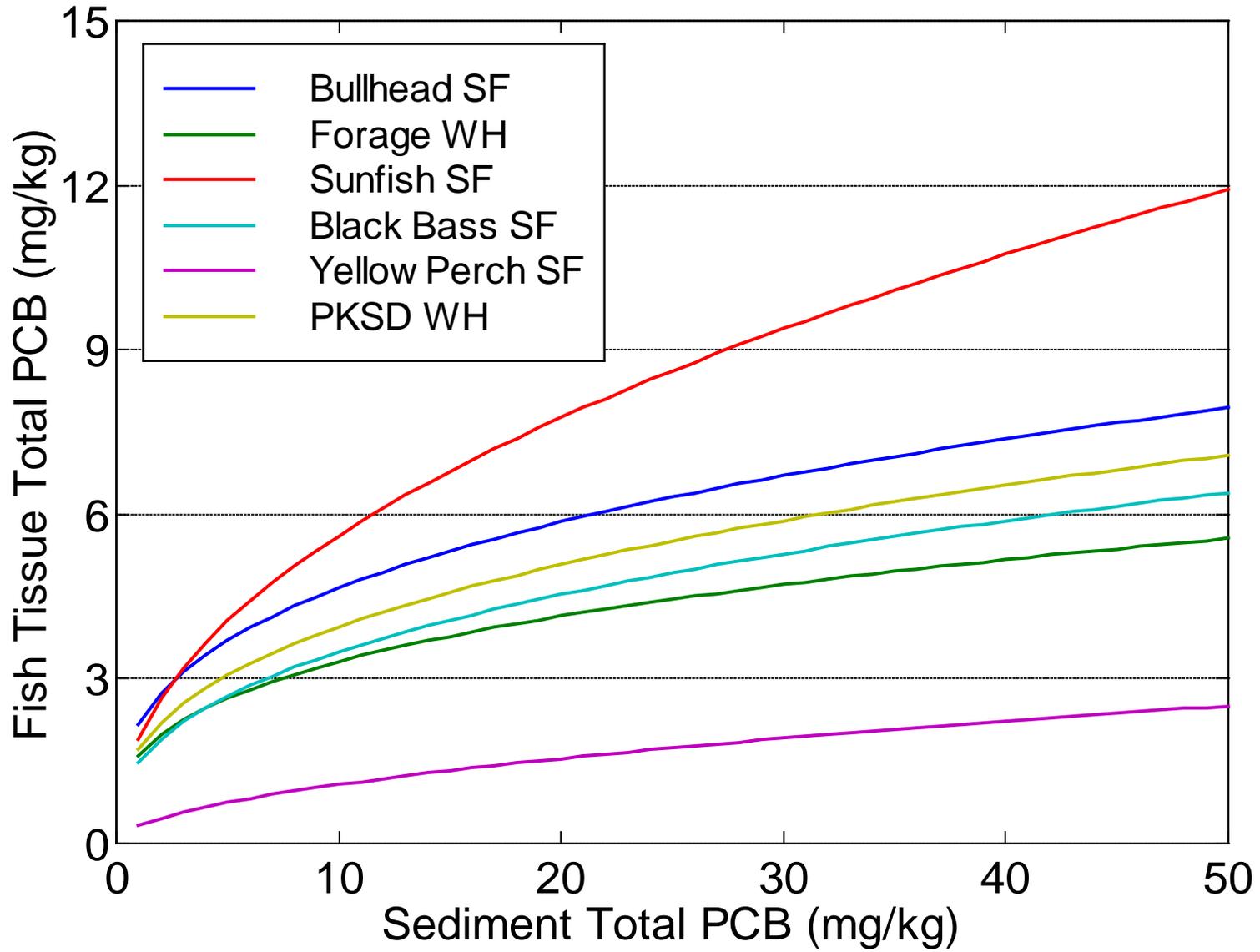


Model Performance

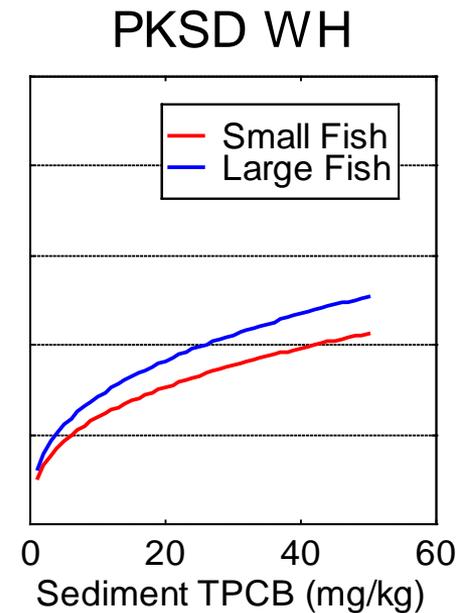
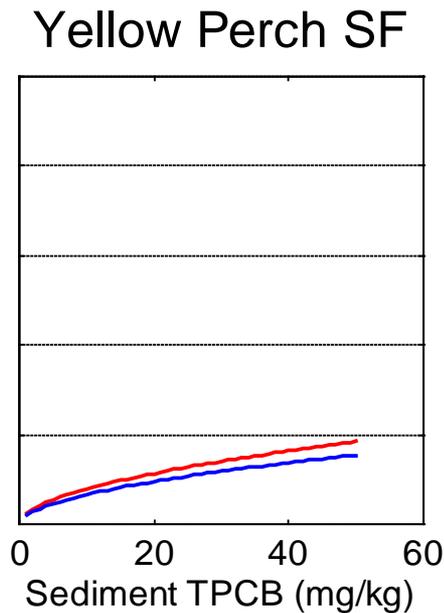
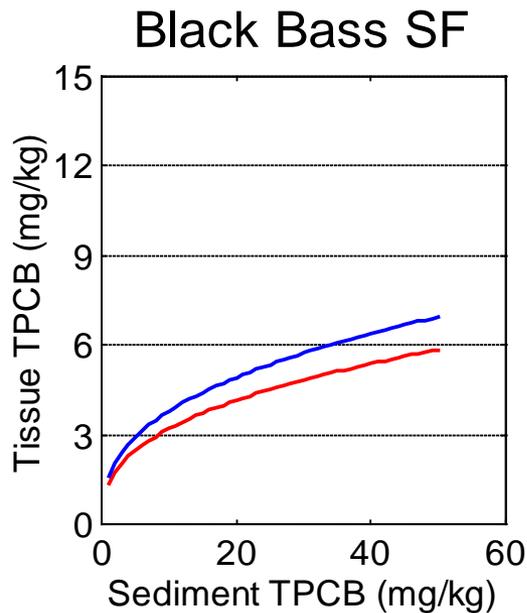
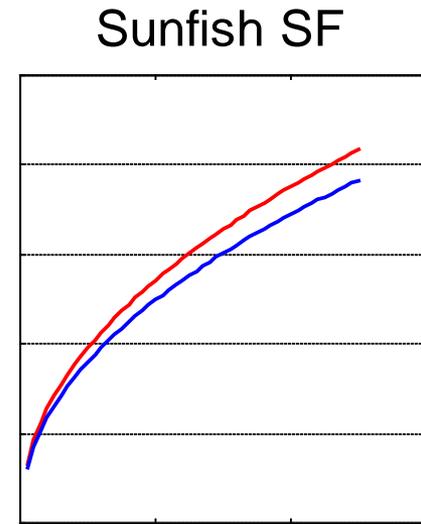
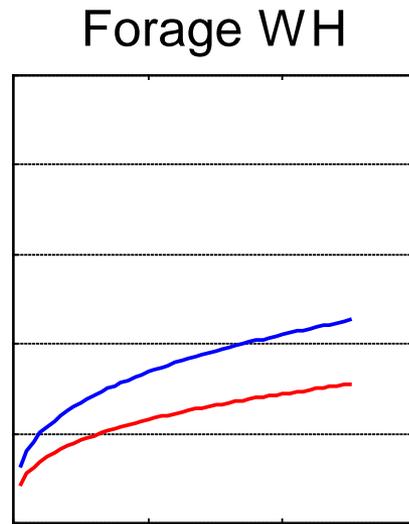
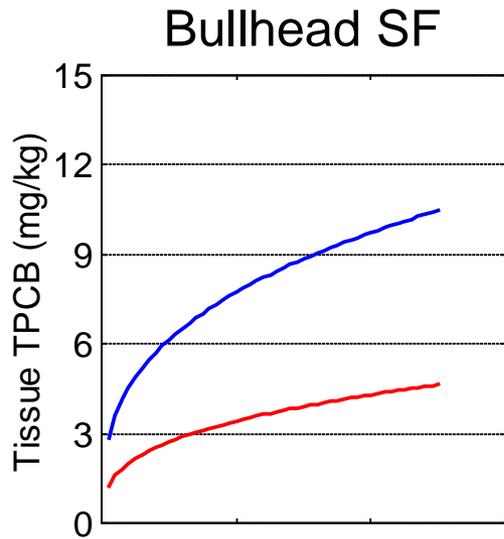
Observed/Predicted: Bullhead



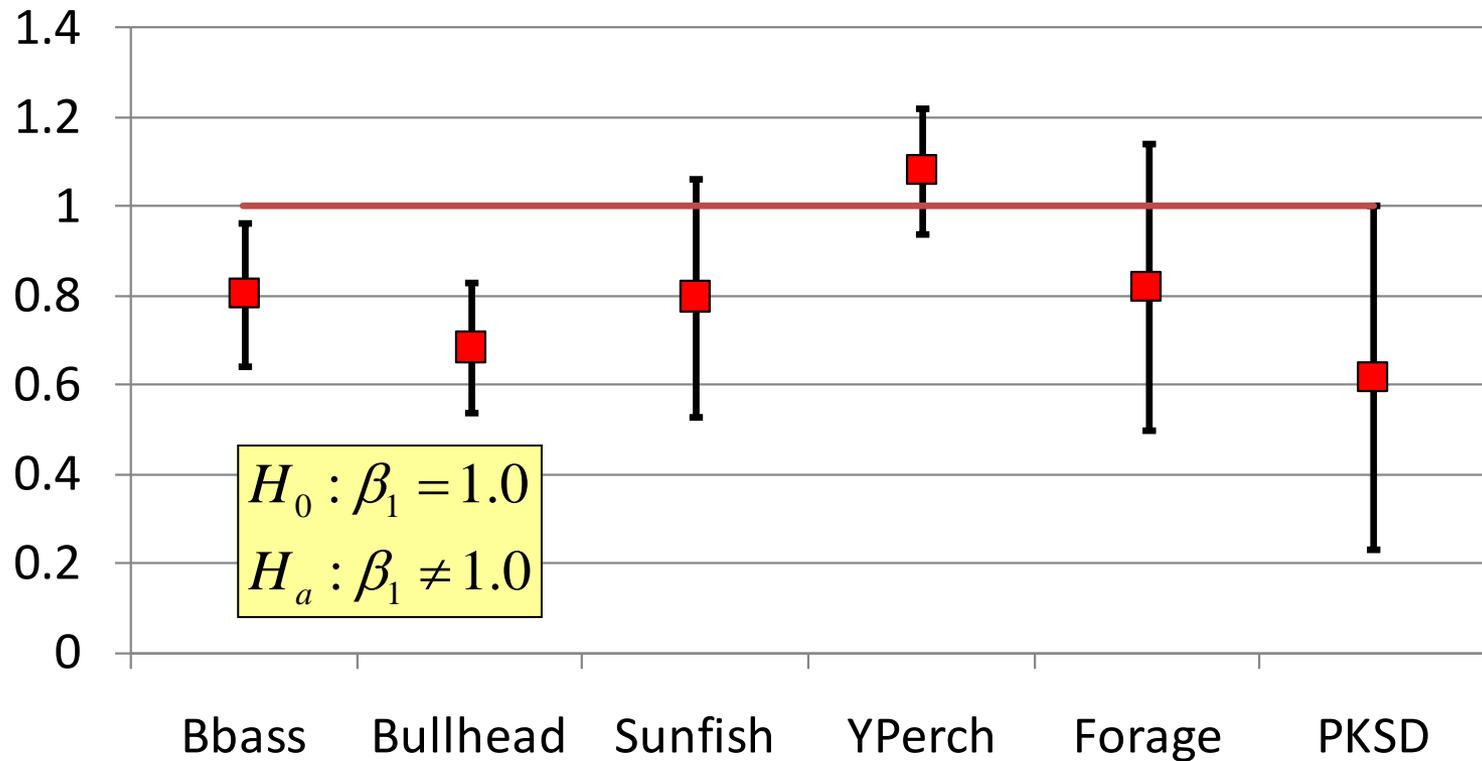
Predicted Fish Tissue vs. Sediment



Fish Length (5th & 95th Percentile)

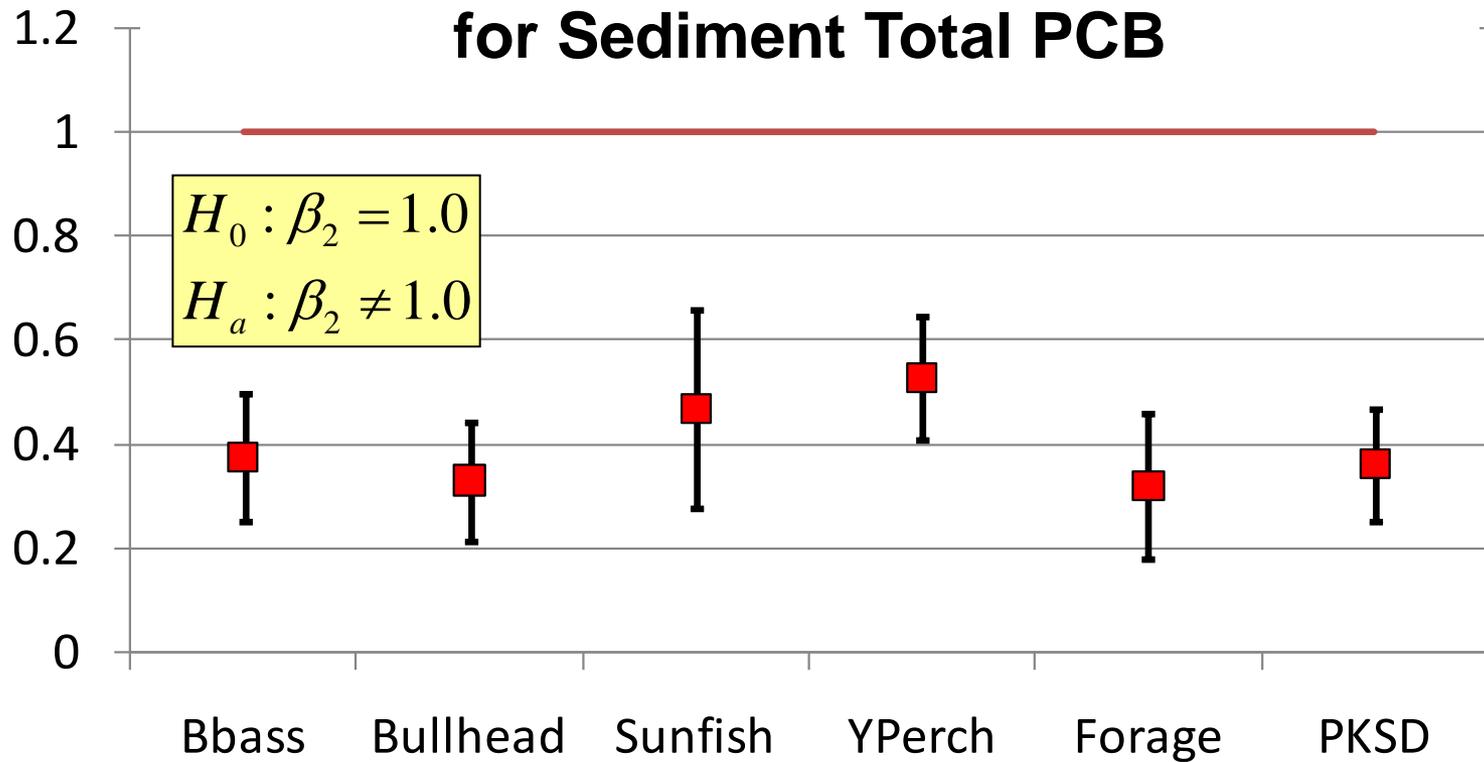


Regression Coefficients for Lipid



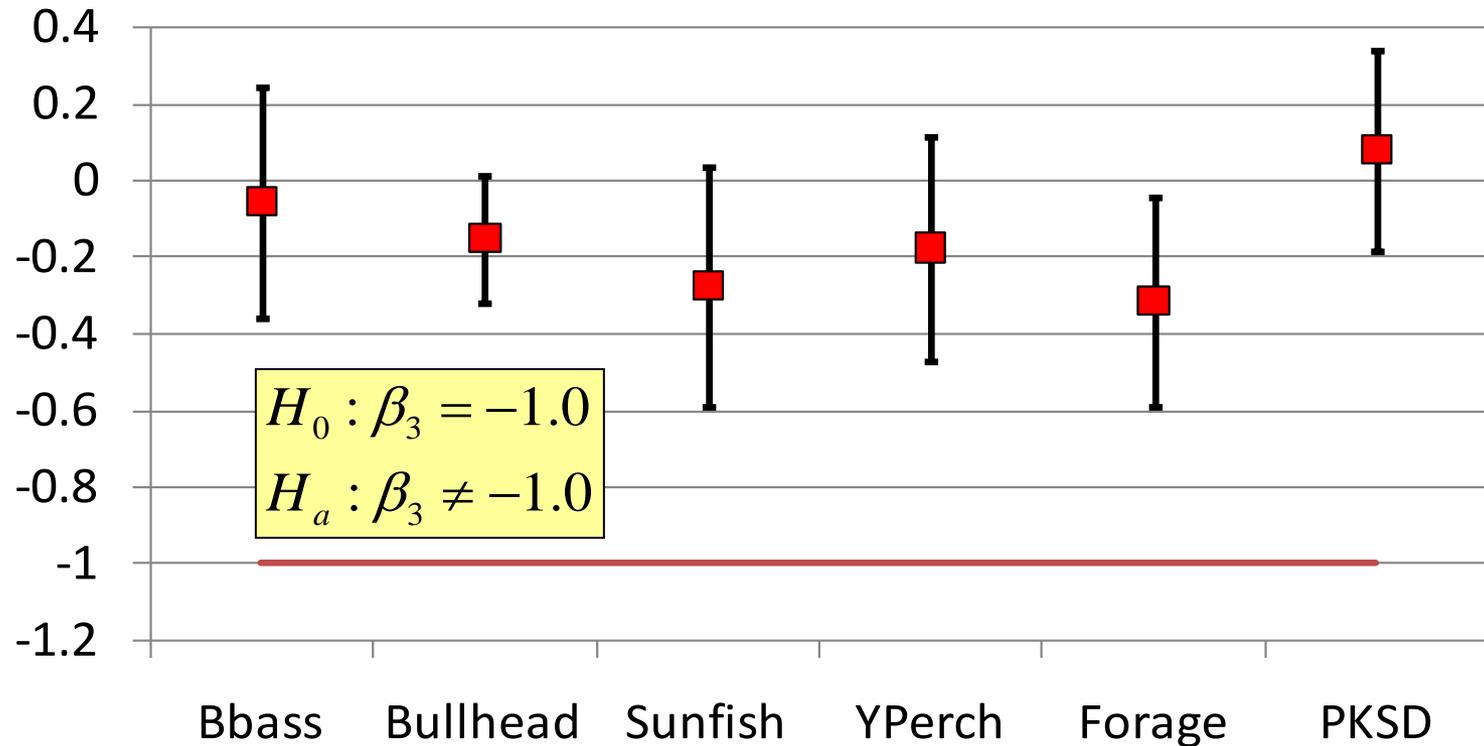
$$BSAF = \frac{\left(C_f / f_{Lipid}^{\beta_1} \right)}{\left(C_s^{\beta_2} / f_{OC}^{-\beta_3} \right)} \Leftrightarrow \beta_1 = \beta_2 = -\beta_3 = 1.0$$

Regression Coefficients for Sediment Total PCB



$$BSAF = \frac{(C_f / f_{Lipid}^{\beta_1})}{(C_s^{\beta_2} / f_{OC}^{-\beta_3})} \Leftrightarrow \beta_1 = \beta_2 = -\beta_3 = 1.0$$

Regression Coefficients for Organic Carbon



$$BSAF = \frac{\left(C_f / f_{Lipid}^{\beta_1} \right)}{\left(C_s^{\beta_2} / f_{OC}^{-\beta_3} \right)} \Leftrightarrow \beta_1 = \beta_2 = -\beta_3 = 1.0$$

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.

Summary --- 2

- 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