Modeling PCBs Residues in Fish Tissue Based on Sediment PCBs Concentration

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BUI 1: Fish Consumption Advisory

Objective: To develop a spatially-explicit model to predict polychlorinated biphenyls (PCBs) concentration in fish tissues that can be used to identify areas where sediment contamination is contributing to the fish consumption advisory.

Currently, there are fish consumption advisories in the St. Louis River Area of Concern related to both mercury and PCBs.

Under Beneficial Use Impairment (BUI) 1, Fish Consumption Advisories, there are two conditions under which the BUI can be removed:

- There are no fish consumption advisories; or
- The resident fish are not significantly elevated compared to regional background samples (St. Louis River watershed, upstream of the reservoirs)

MEAL ADVICE CATEGORIES BASED ON LEVELS OF PCBs IN FISH

Level of PCBs in Fish (ppm)	Meal Frequency
< = 0.05	Unrestricted
> 0.05 – 0.22	1 meal / week
> 0.22 – 0.95	1 meal / month
> 0.95 – 1.89	1 meal / 2 months
> 1.89	DO NOT EAT

Minnesota guidelines for fish consumption based on total PCBs concentration in fish fillets.

Source: Minnesota Department of Health

Note: 0.05 ppm = 50 ppb

Strategy for AOC Decision-Support

- Develop a habitat-specific, geospatial Biota-Sediment Accumulation Factor (BSAF) model that predicts fish tissue residues for Yellow Perch (*Perca flavescens)* based on both sediment quality and habitat quality
- Conduct a field validation of the model based on random, stratified sampling
- Develop a high-resolution (10 m) version to support remedy decision-making

Model Development

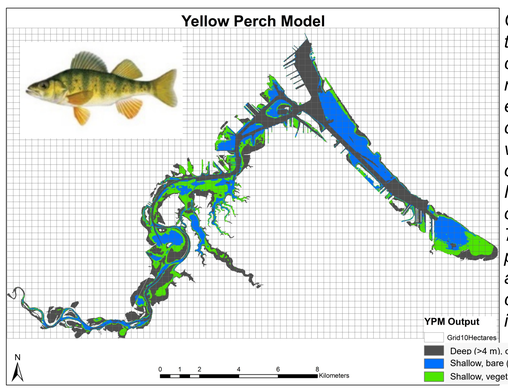
Biota-Sediment Accumulation Factor (BSAF) model to predict fish tissue concentration based on PCBs and total organic carbon (TOC) in sediment:

$$BSAF = [PCBs_{Biota}] / ([PCBs_{Sediment}] / [TOC_{Sediment}])$$

$$[PCBs_{Biota}] = BSAF * ([PCBs_{Sediment}] / [TOC_{Sediment}])$$

From EPA BSAF database for Yellow Perch

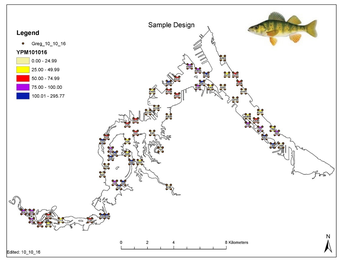
- 1.21 mean value for lower Fox River AOC (median value 3.75)
- Tissue lipid content = 1%
- Accounts for proportion benthic diet, trophic level



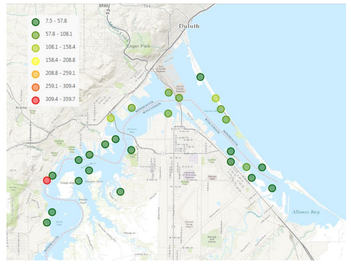
Computational grid for the BSAF model. Grid cells represent a home range of 10 ha. Fish exposure is habitat dependent (50% vegetated habitat, 50% open water habitat). Model assumes habitat optimum <4 m and 25-75% vegetation probability (Angradi et al. 2013). Each cell is computationally independent.

Model Validation

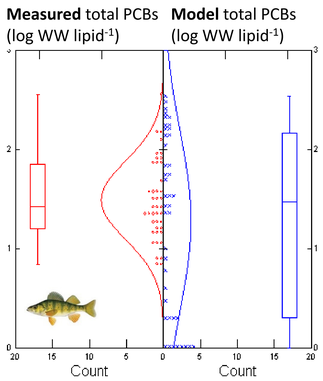
- Sampling sites chosen at random, stratified by predicted concentration
- Targeted ten composites per each of 5 stratum (shown below); n = 44
- Composites: 3-5 Yellow Perch (75-150 mm total length; 2-3 year-old fish)



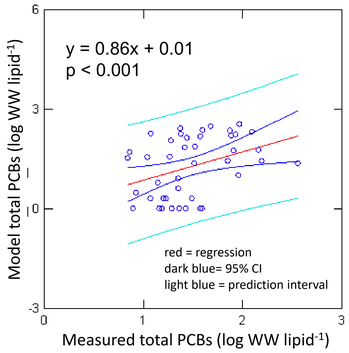
Sampling design for the field validation of the BSAF model. Yellow Perch were collected from within each selected grid cell.



Yellow Perch composite whole fish total PCBs (ppb; wet weight lipid^{-1}) from field validation samples.

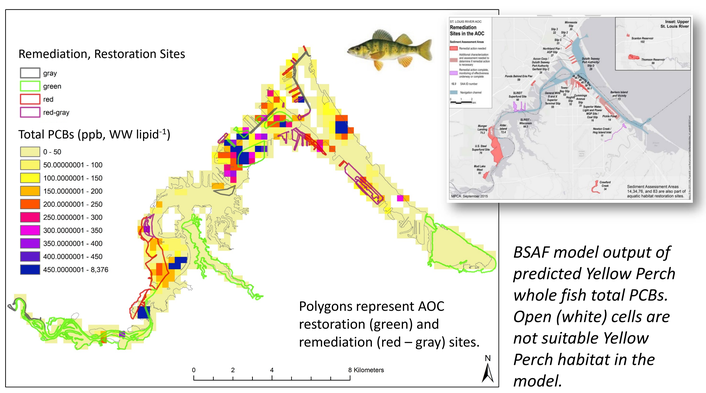


Frequency distributions of composite whole fish total PCBs (ppb; wet weight lipid^{-1}) from field validation samples (left) versus model output (right).



Regression of BSAF model output versus measured Yellow Perch whole fish composite total PCBs (ppb; wet weight lipid^{-1}).

Lower St. Louis River BSAF Model Results

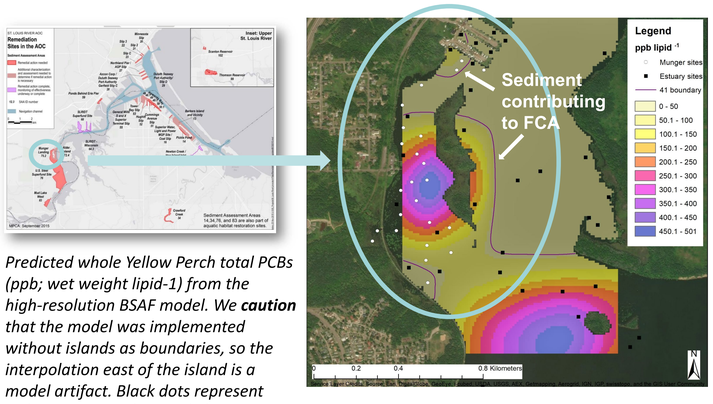


BSAF model output of predicted Yellow Perch whole fish total PCBs. Open (white) cells are not suitable Yellow Perch habitat in the model.

Munger Landing Remediation Support

To support decision-making regarding the project footprint, we developed a high-resolution simulation of the BSAF model:

- 1,024 runs, randomly varying the starting location of the computational grid
- Re-sampled at 10 m grid
- Calculated the arithmetic mean of 1,024 runs



*Predicted whole Yellow Perch total PCBs (ppb; wet weight lipid-1) from the high-resolution BSAF model. We **caution** that the model was implemented without islands as boundaries, so the interpolation east of the island is a model artifact. Black dots represent sediment cores. The purple line represents the total PCBs concentration in sediment (~40 ppb, assuming 5% TOC) associated with 50 ppb total PCBs in whole Yellow Perch, a proxy for a fish consumption advisory (FCA).*

The model indicates that dredging within the area defined by the purple line would remove sediment of sufficiently high concentration that it is likely contributing to the current fish consumption advisory.

Discussion

- Total PCBs in whole fish composites varied widely; elevated concentrations in some samples are consistent with the current fish consumption advisory
- The BSAF model accurately predicts fish tissue residues
  - Demonstrates sediment quality is the main factor influencing fish tissue concentrations
  - Corroborates previous studies demonstrating Yellow Perch have small home ranges and are therefore a useful species for biomonitoring
  - Indicates that the background sediment concentration in the AOC does not produce fish of sufficiently high total PCBs to warrant a fish consumption advisory
- The BSAF model suggests that there are areas outside of current red zones targeted for remediation where the bioaccumulative potential is of concern. We interpret the model as a "smoke alarm" that identifies areas of potential concern which merit greater investigation.
- The applied high-resolution BSAF model can support remediation design, and could also be used to design targeted biomonitoring.

References and Acknowledgements

Angradi, T.R., M.S. Pearson, D.W. Bolgrien, B.J. Bellinger, M.A. Starry, C. Reschke. 2013. Predicting submerged aquatic vegetation cover and occurrence in a Lake Superior estuary. Journal of Great Lakes Research 39:536-546.

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