Great Lakes Areas of Concern (AOC): U.S. EPA Research on Assessing Remedy and Restoration Success

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March 4, 2014 2014 **Great Lakes Conference: Issues and Innovations**

The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA


Budget
Make The BETTER Move

Outline

Background

Great lakes Legacy Act (GLLA) and Restoration Initiative (GLRI)

Areas of Concern (AOCs) and Beneficial Use Impairment (BUIs)

Biological Indicators

Brown Bullhead Comet Assay

Macroinvertebrate Body Burden – Hester Dendies (HDs) – Multi Plate Samplers (MPS)

Macroinvertebrate Biological Integrity Indices (MBII) – Eco HDs/MPS

Riparian Spiders – Tetragnathids

AOC Studies

Ashtabula River – Ohio 2006-2011

Ottawa River – Ohio – 2009-2013

West Branch Grand Calumet River – Indiana 2012

Manistique River – UP Michigan - 2013

2014-2015 – Niagara River

Great Lakes Legacy Act (GLLA)
Great Lakes Restoration Initiative (GLRI)

United States Environmental Protection Agency

GLLA

The Legacy Act authorizes funding for contaminated sediment projects in the Great Lakes.

Project must be in U.S. AOCs and:

(i) Monitor or evaluate contaminated sediment;

(ii) Implements a plan to remediate contaminated sediment; or

(iii) Prevent further or renewed sediment contamination.

GLRI

The GLRI is the largest investment in the Great Lakes in two decades. A task force of 11 federal agencies **developed an action plan to implement the initiative. This action plan covers fiscal years 2010 through 2014 and addresses five urgent issues:**

- **Cleaning up toxics and areas of concern;**
- **Combating invasive species;**
- **Promoting nearshore health by protecting watersheds from polluted run-off;**
- **Restoring wetlands and other habitats; and**
- **Tracking progress and working with strategic partners.**

Courtesy of Amy Mucha

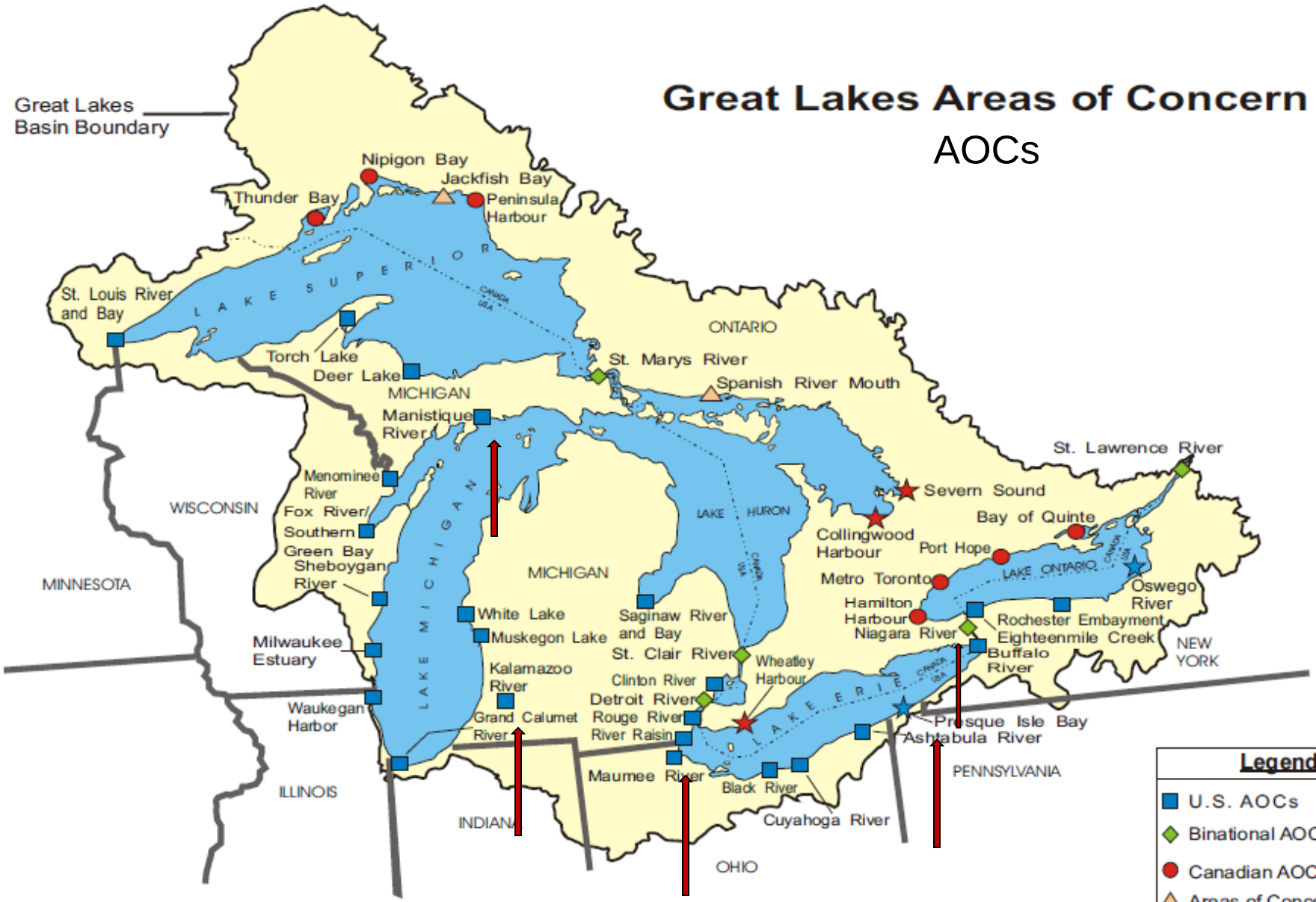
What is an Area of Concern (AOC)?

Area of Concern (AOC) – Designated Great Lakes "Hot Spots" under the U.S.- Canada Great Lakes Water Quality Agreement.

Although releases of toxic pollutants have been reduced significantly over the last 30 years, **there is a legacy of contamination in sediments and continuing inputs through rivers and air**. Excessive levels of contaminants are still found in fish throughout the system.

43 AOCs have been identified:
26 located entirely within the U. S.
12 located wholly within Canada; and
5 that are shared by both countries.

Courtesy of Amy Mucha



Courtesy of Amy Mucha

How Impact is Defined ⇨ BUIs

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14 Possible Beneficial Use Impairments (BUIs)

1. **Restrictions on Fish and Wildlife Consumption**
2. Tainting of Fish and Wildlife Flavor
3. Degraded Fish and Wildlife Populations
4. **Fish Tumors or Other Deformities**
5. Bird or Animal Deformities or Reproductive Problems
6. **Degradation of Benthos**
7. Restrictions on Dredging Activities
8. **Eutrophication or Undesirable Algae**
9. **Restrictions on Drinking Water Consumption or Taste and Odor Problems**
10. Beach Closings
11. Degradation of Aesthetics
12. Added Costs to Agriculture or Industry
13. **Degradation of Phytoplankton and Zooplankton Populations**
14. Loss of Fish and Wildlife Habitat

Courtesy of Amy Mucha

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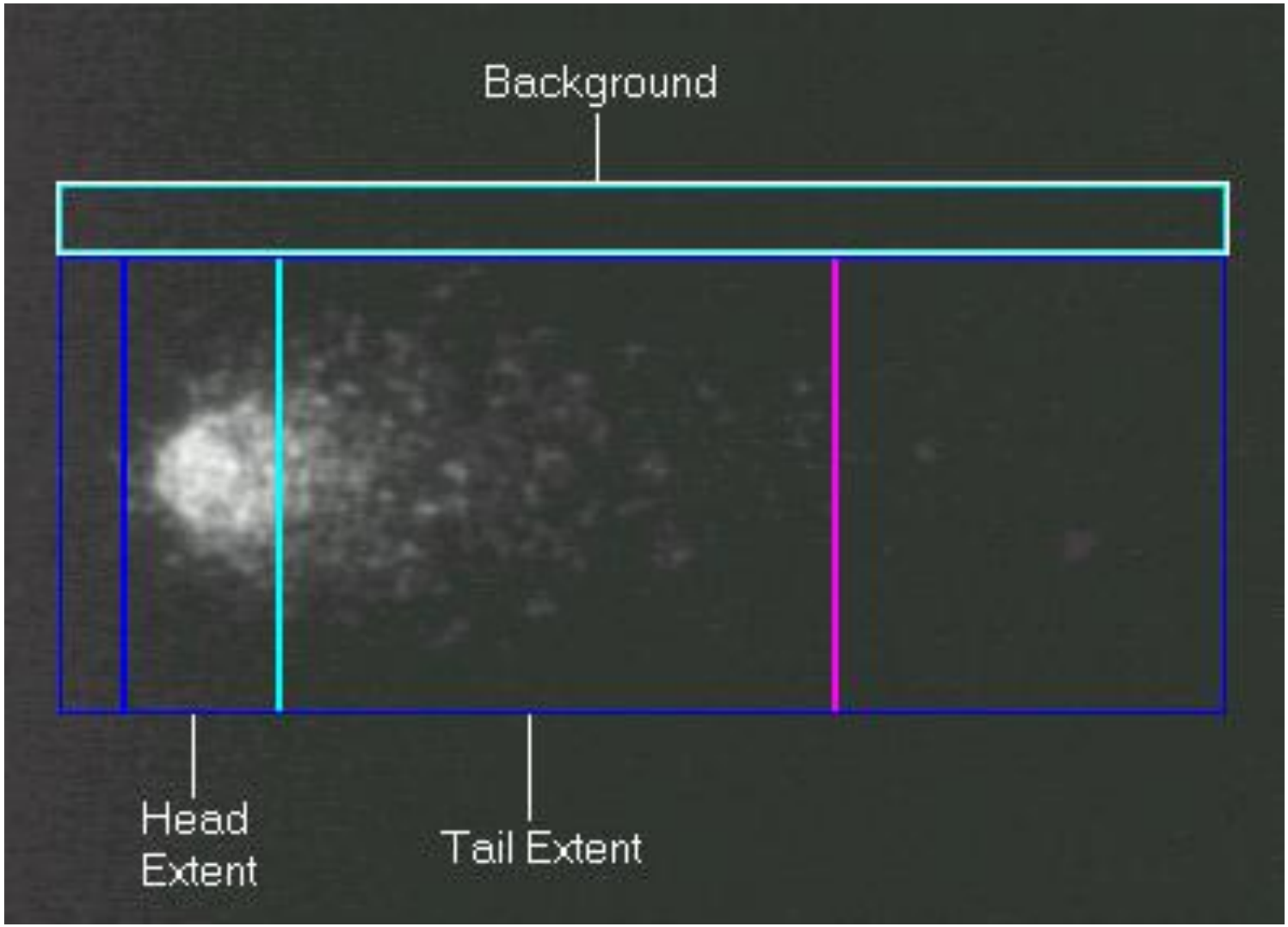
Why Brown Bullheads?

- **Bottom feeders**
- **Live and eat in sediments where pollutants accumulate**
- **Tend to stay in one area ?**
- **Metabolize certain carcinogens Polynuclear Aromatic Hydrocarbons (PAHs) as humans do.**
- **Liver tumors in bullheads have been linked to PAHs**
- **One of two fish species used to assess tumors/other deformities for “beneficial use impairment” for AOCs.**

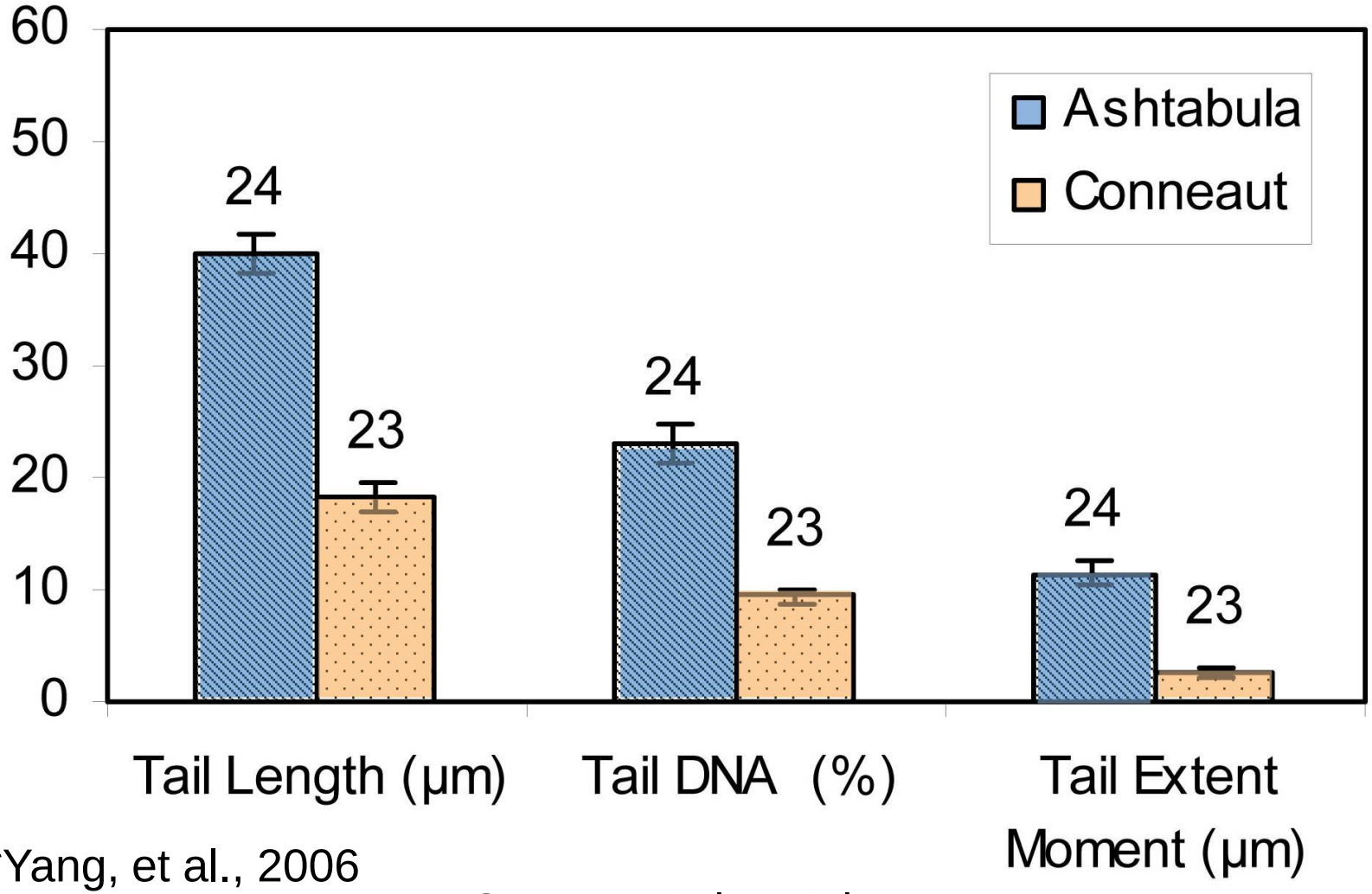
Courtesy John Meier

DNA damage in fish liver and blood
Comet Assay Image Analyses



Courtesy John Meier

DNA Damage in Erythrocytes of Brown Bullheads Collected from Ashtabula River and Conneaut Creek during 2002*



- *Yang, et al., 2006

Courtesy John Meier

Why Sample Macroinvertebrates

- **A majority of the benthic invertebrates, i.e. midge larvae, annelids (aquatic worms), mayfly larvae have life cycles that last 30-90 days.**

- **Body burden values for contaminants in macroinvertebrates provide very recent exposure levels.**

Why Sample Riparian Spiders

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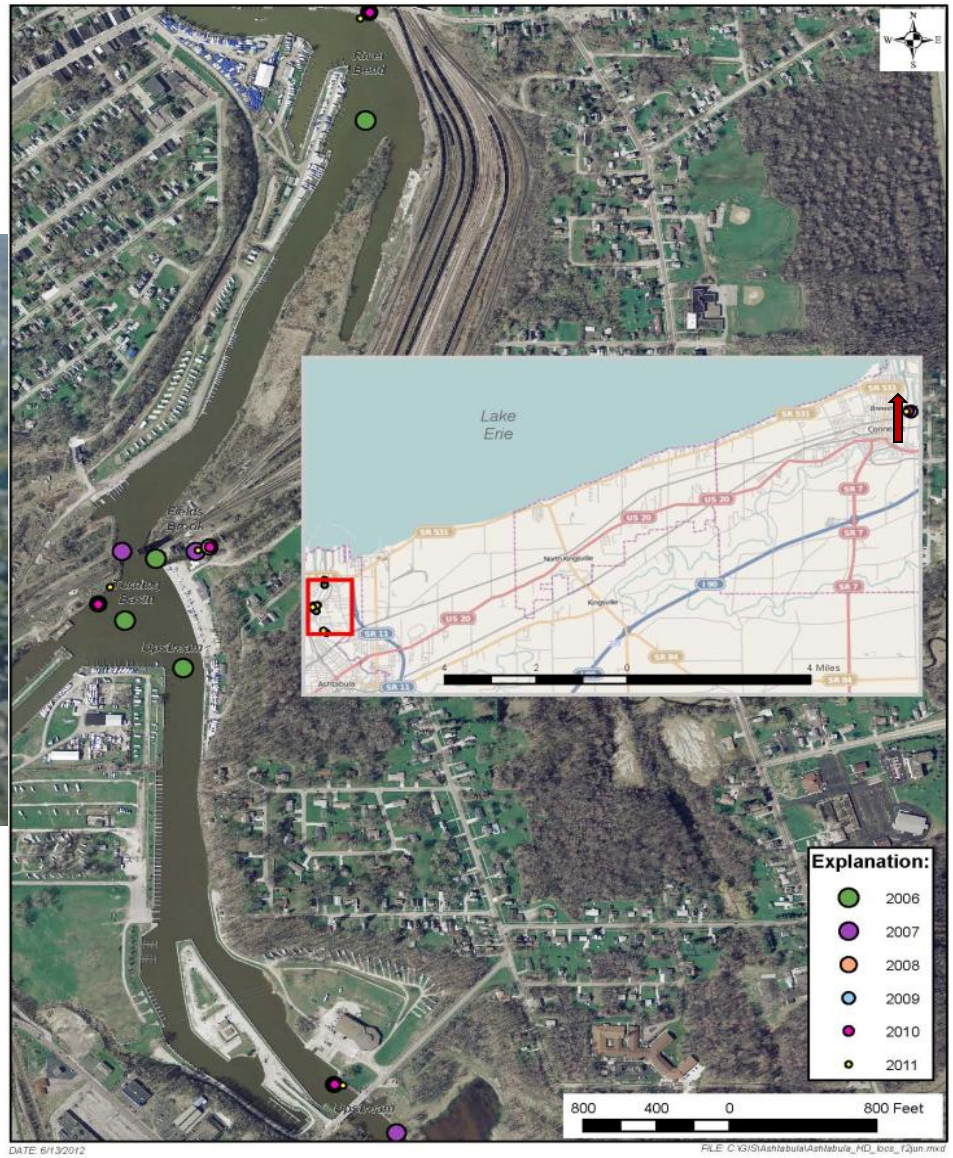
Criteria	Attributes
•Integrate environmental exposures	• tissues/populations correlated with environmental concentrations
•Easy to sample	• high abundance • high n
•Interpretation •straightforward	• sedentary • aquatic insect specialist
•Cross-system comparisons	• near global distribution • all freshwater habitats
•Ethical concerns (destructive sampling)	• few

•Tetragnathid spider

Walters et al. 2008. Ecol. App.
Walters et al. 2010. ES&T

Ashtabula AOC & Reference Stream

United States Environmental Protection Agency



Contaminant Characteristics of Study Sites

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Site	Classification	Types of Contaminants	Source of Contaminants
Ashtabula River[a]	Contaminated	PCBs, PAHs, metals,	Industrial, agricultural runoff, ship traffic
Conneaut Creek	Reference	(PAHs?)	Agricultural runoff, ship traffic

NA: not available

[a]Designated Great Lakes Area of Concern

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Beneficial Use Impairments

- **Restrictions on fish and wildlife consumption**
- **Degradation of fish and wildlife populations**
- **Fish tumors or other deformities**
- **Degradation of benthos**
- **Restriction on dredging activities**
- **Loss of fish and wildlife habitat**

Biological Indicators used to assess remedy effectiveness

- **Body burdens of PCBs and PAHs in benthic macroinvertebrates**
- **Whole fish tissue concentrations of PCBs and PAHs in indigenous fish**
- **DNA damage in fish liver and blood**
- **Examination of external lesions and anomalies in fish**
- **Fish liver histopathology (pre-dredging and post-dredging)**

ORD's Goals

- **Use chemical, physical and biological tools to assess the effectiveness of the remediation**

- **To transfer the technology from what we learn to other sites**

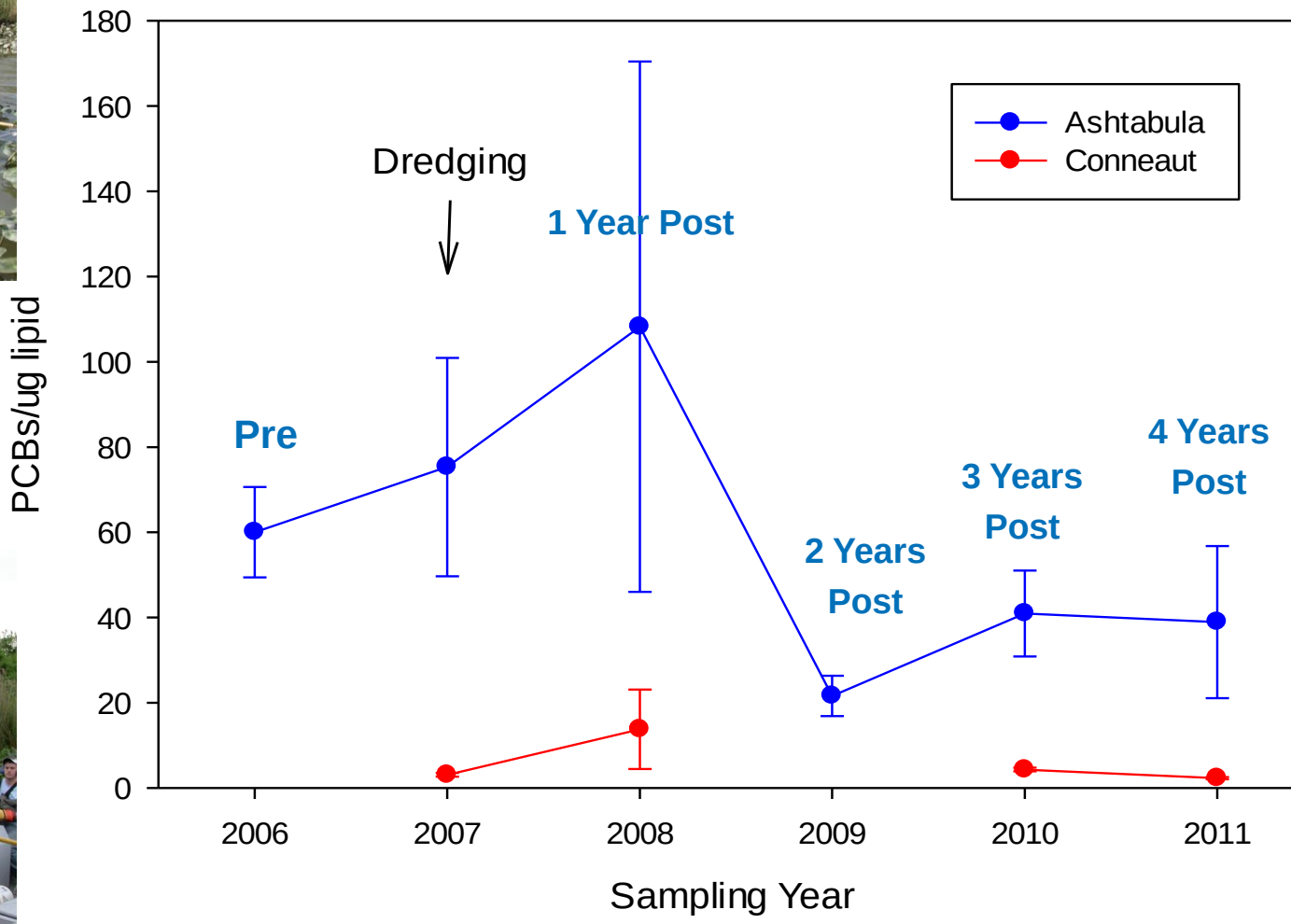
Specific Objective

- **Evaluate biological indicators to characterize contaminant exposure before, during, and following dredging.**

Results – Bullhead PCBs Tissue Levels

United States Environmental Protection Agency

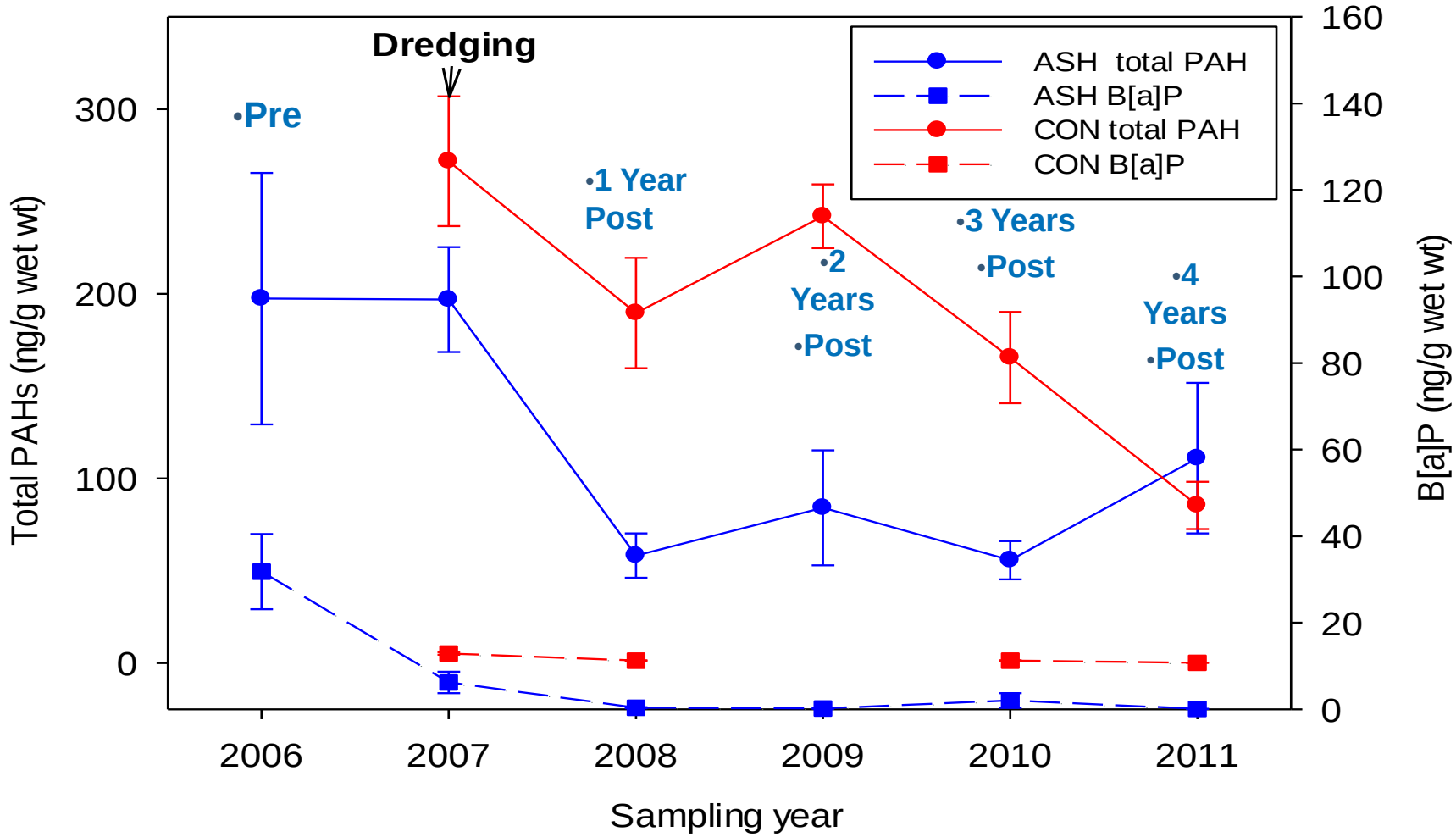
Total lipid-normalized PCBs in Ashtabula R. and Conneaut Cr. Brown Bullheads



Results – Bullhead PAH Tissue Levels

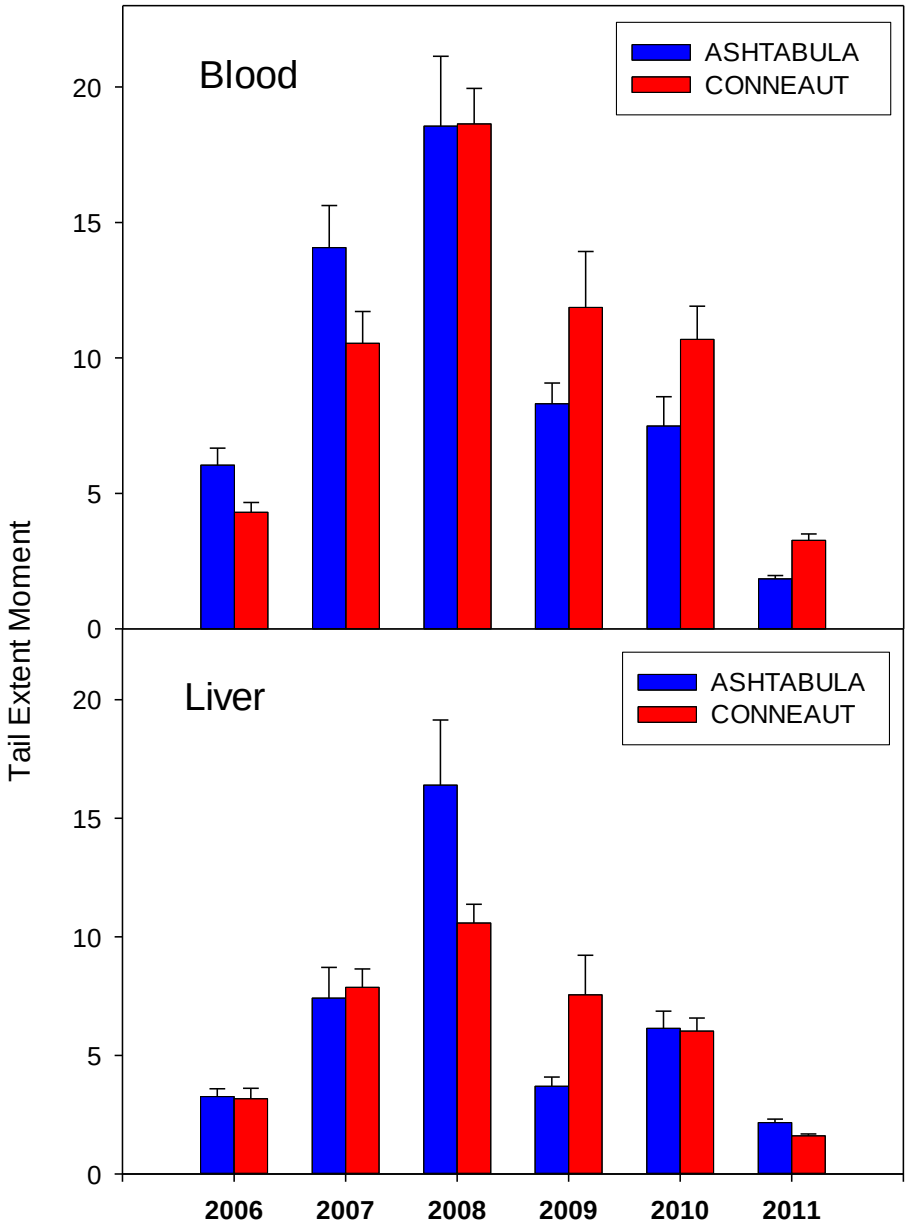
United States Environmental Protection Agency

Total PAHs and B[a]P in Ashtabula and Conneaut Brown Bullheads



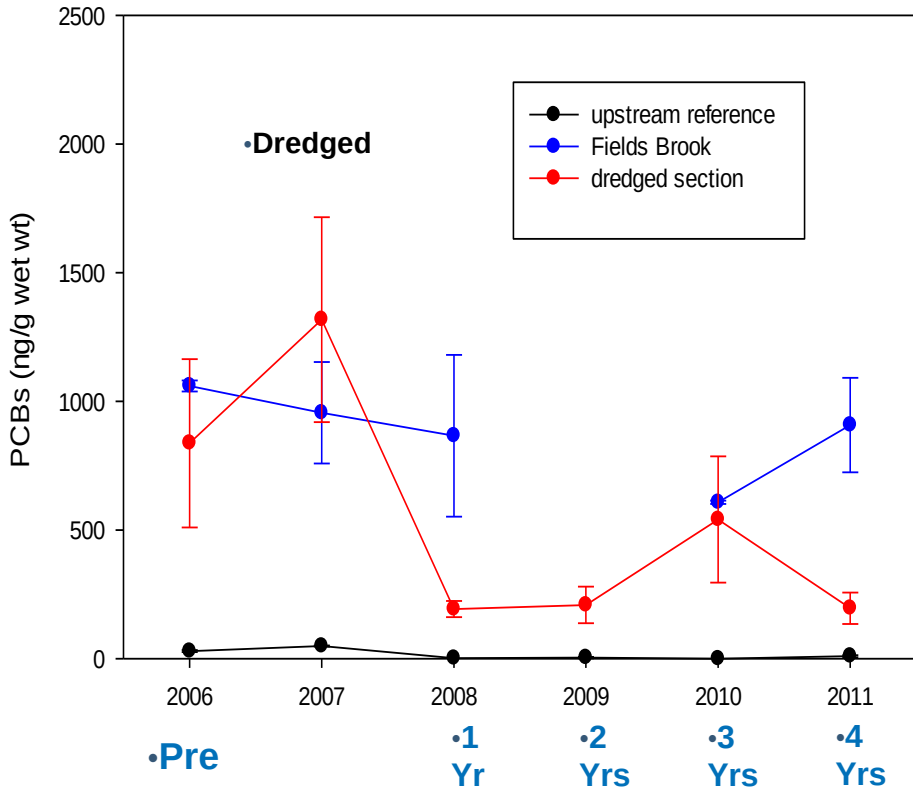
United States Environmental Protection Agency

DNA Damage in Blood and Liver of Brown Bullheads Collected from Ashtabula R. and Conneaut Cr.

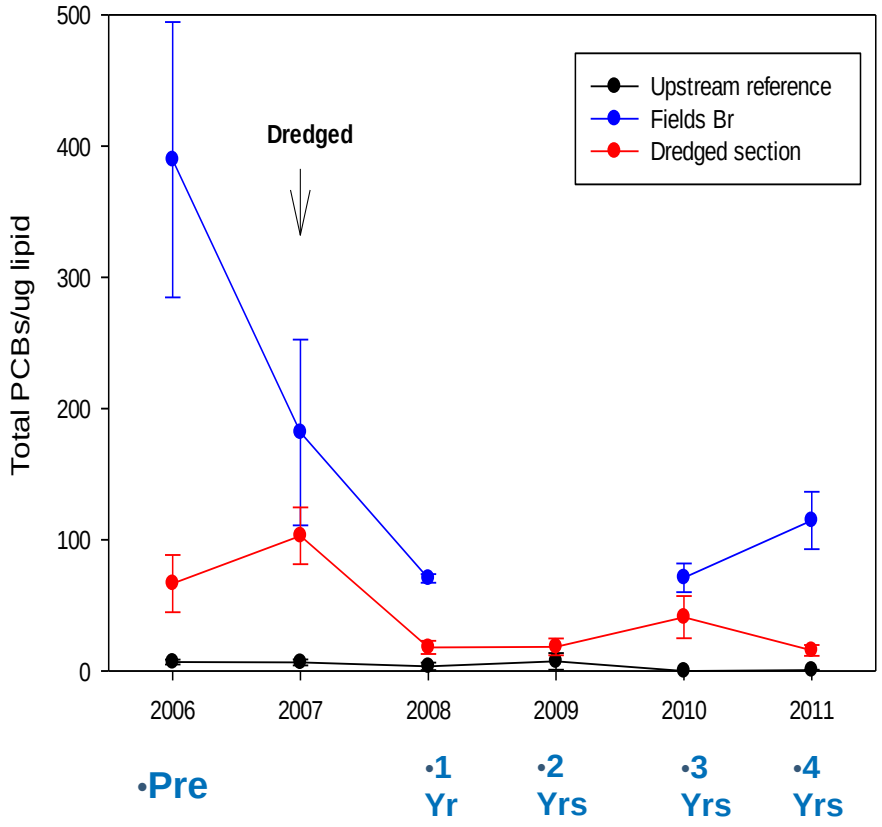


Results – PCB Macroinvertebrates

PCB levels in macroinvertebrates at Ashtabula R.



Total PCBs in macroinvertebrates normalized to lipid content



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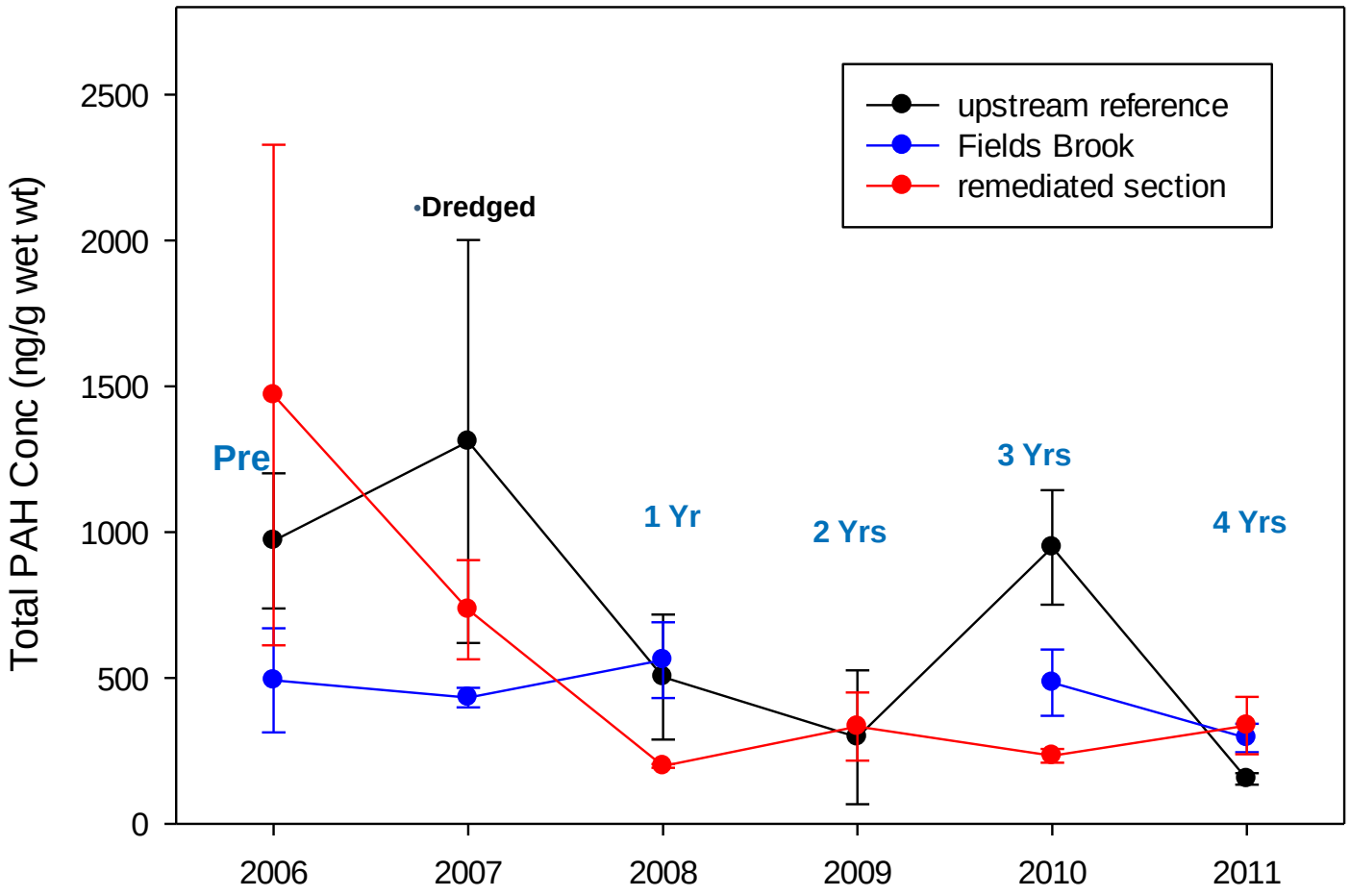
Total PAHs in Macroinvertebrates collected from Ashtabula R.



Summary of Findings

1) Body burden PCBs and PAHs in indigenous macroinvertebrates and fish: concentrations showed an expected trend – same or increasing levels during dredging - downward trend in first year post dredging.

2) Reference site may not be suitable for comparing DNA damage in fish since PAH body burdens were found to be similar.

3) Mass removal of PCBs was obtained by dredging; however, surface sediment concentrations of PCBs remained high immediately post-dredging likely due to surface residuals.

Macroinvertebrates HDs/MPS Deployed

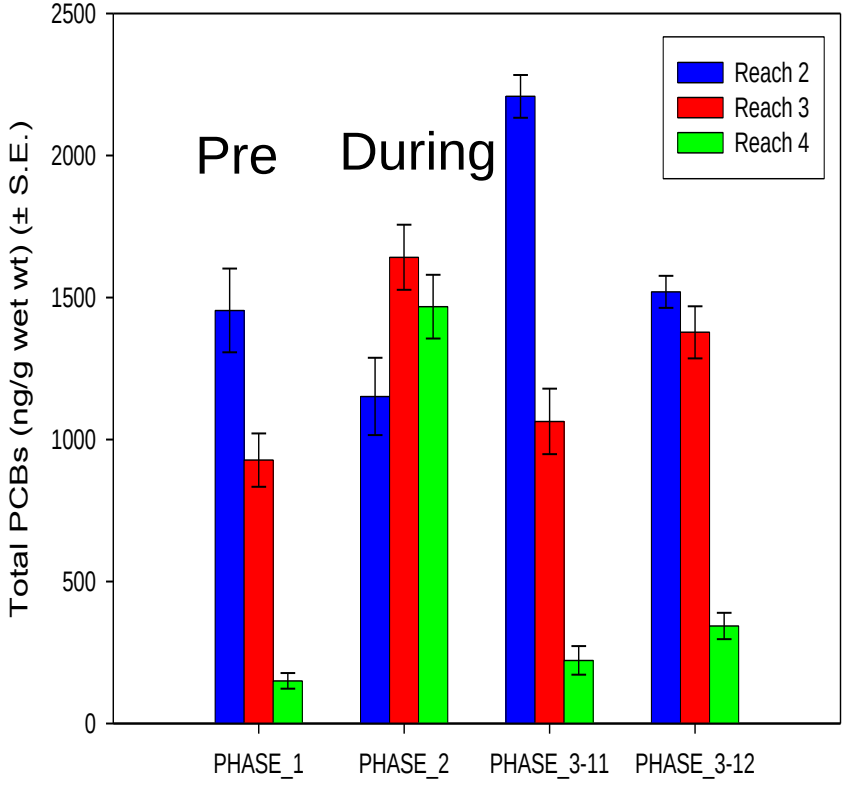
18 sites Ottawa River (9 Dredged/9 Undredged)

EPA United States Environmental Protection

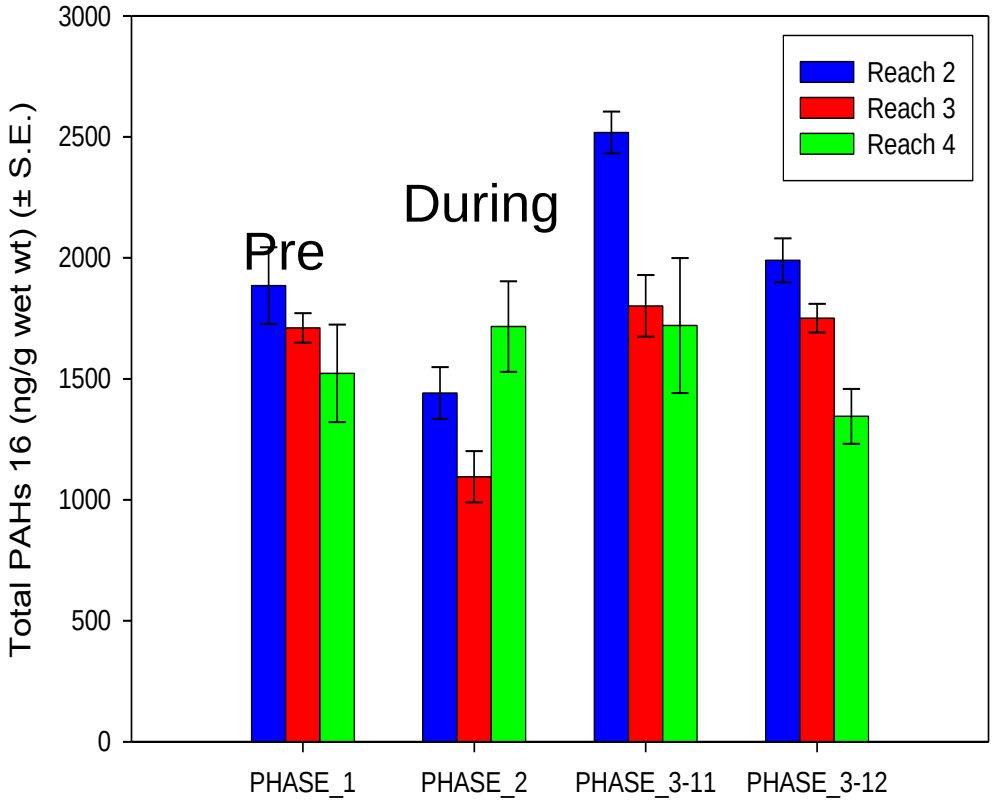
Average Concentrations in Macroinvertebrates from HDs/MPS Deployed in the Ottawa River During Phases 1, 2, 3-11, 3-12

United States Environmental Protection Agency

PCBs



PAHs



Invertebrate multi-metric scores – 6 sites Co-Located with Body Burden HD/MPS

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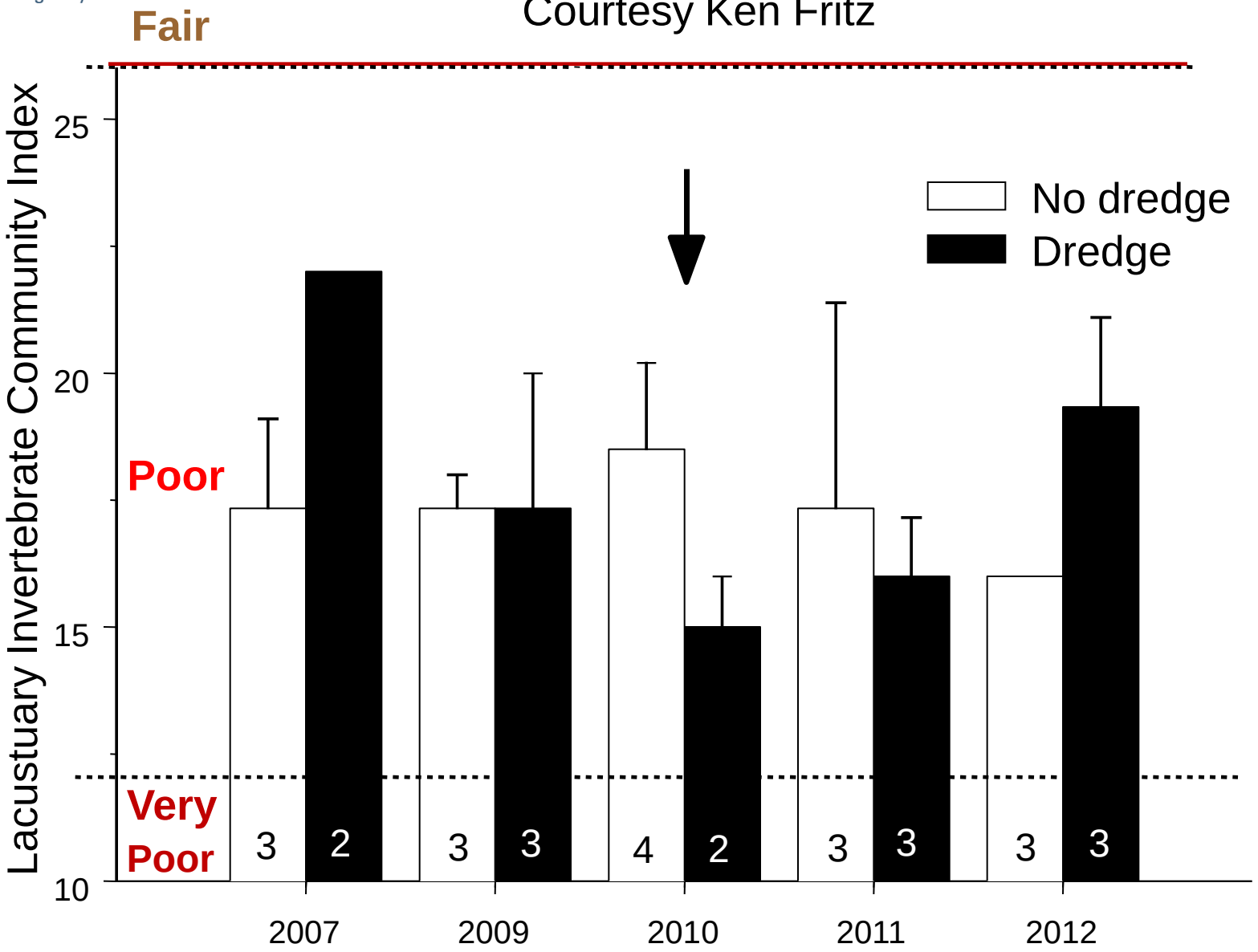
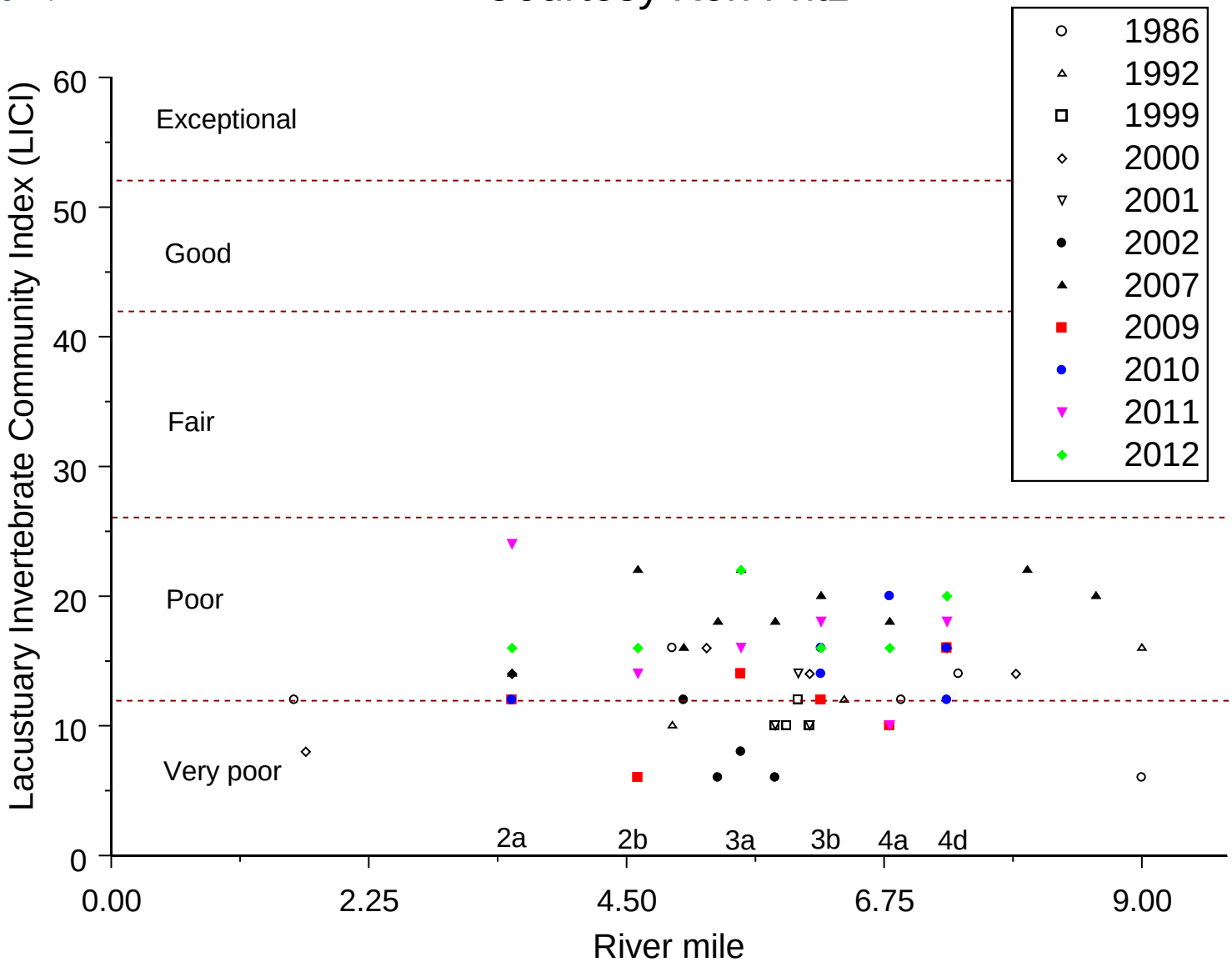
Courtesy Ken Fritz



Invertebrate multi-metric scores

United States Environmental Protection Agency

Courtesy Ken Fritz



Larval insect Vs. spider PCBs over time

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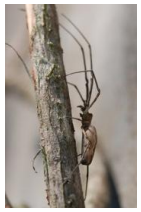
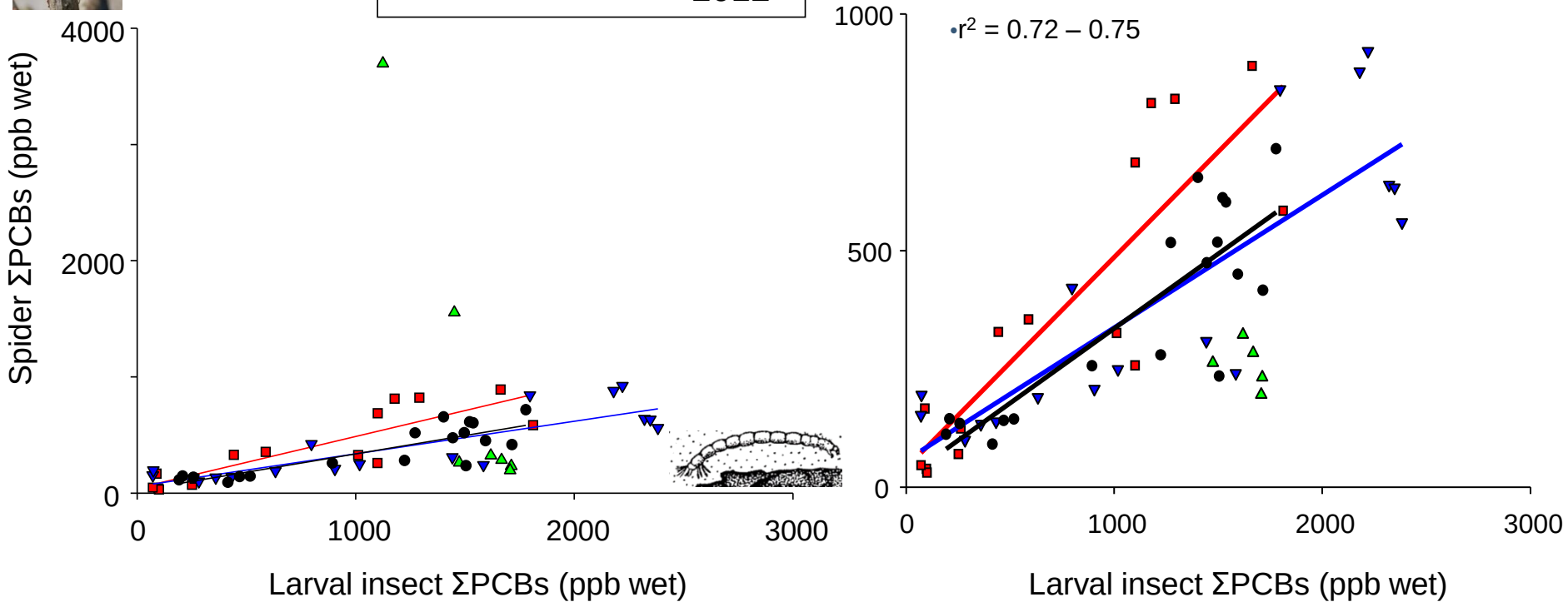
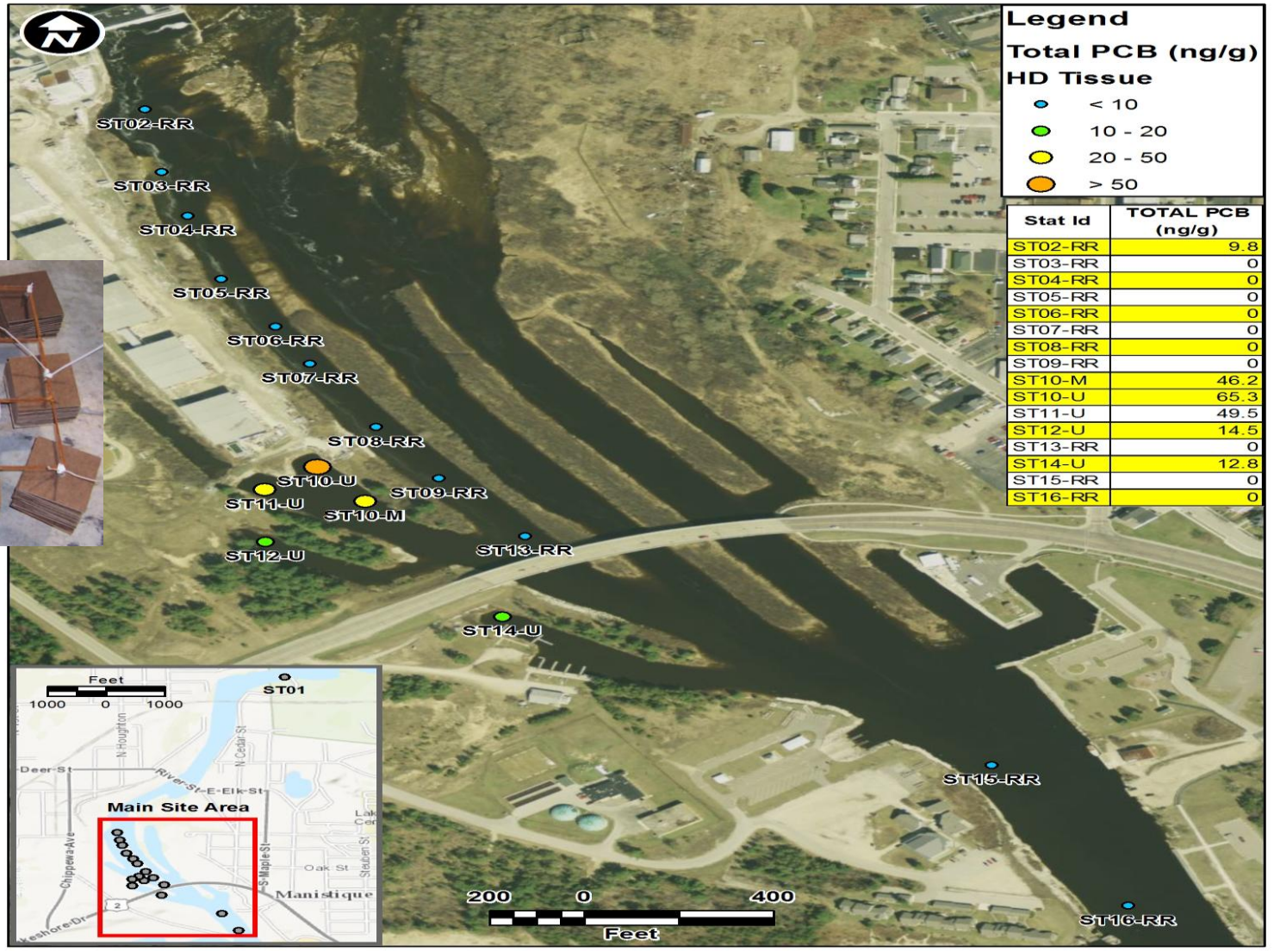


Courtesy David Walters



18 sites in Ottawa River

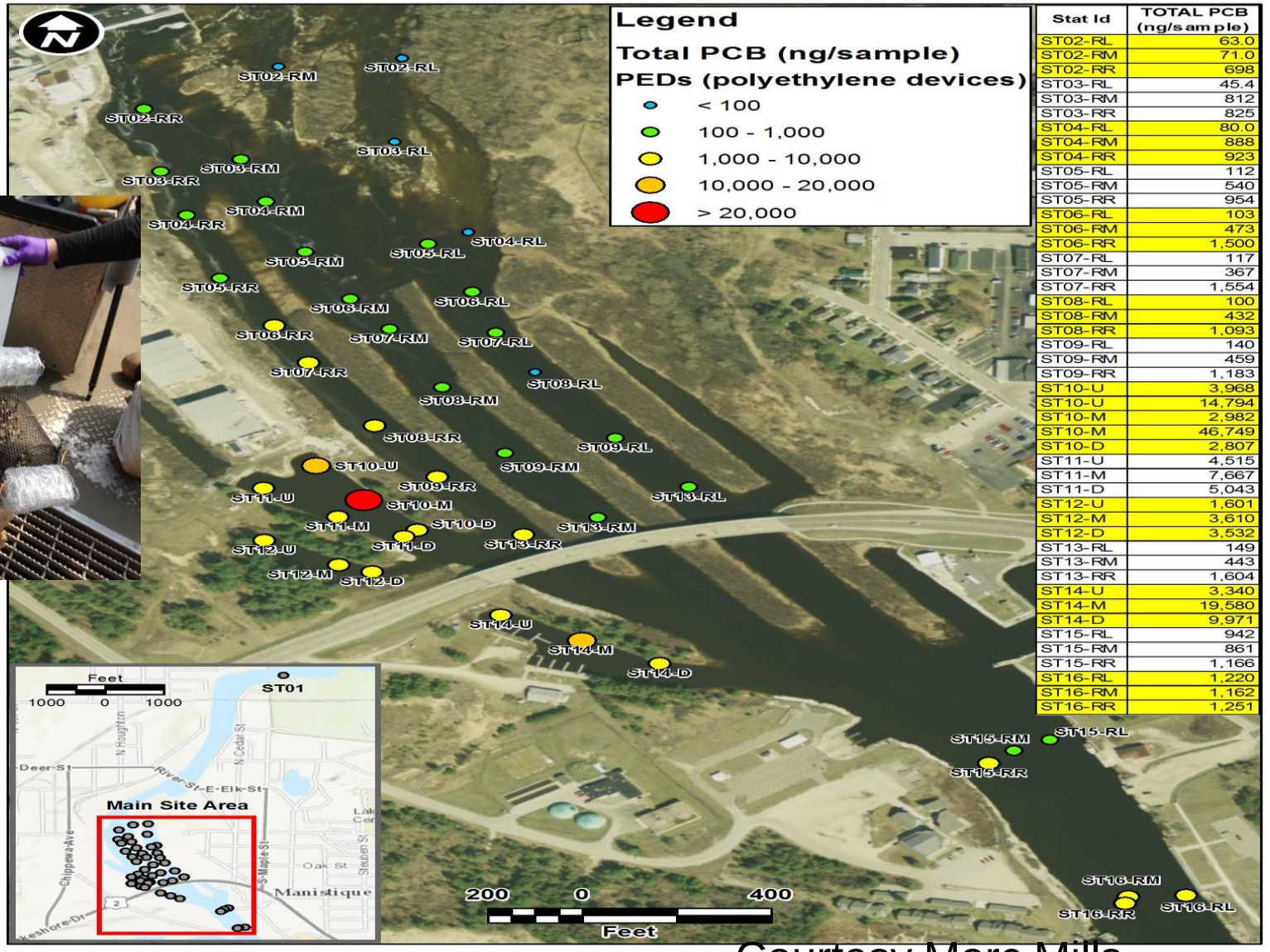
2012 Manistique AOC Macrobenthos (HD/MPS) – tPCBs – SourceTracking



Stat Id	TOTAL PCB (ng/g)
ST02-RR	9.8
ST03-RR	0
ST04-RR	0
ST05-RR	0
ST06-RR	0
ST07-RR	0
ST08-RR	0
ST09-RR	0
ST10-M	46.2
ST10-U	65.3
ST11-U	49.5
ST12-U	14.5
ST13-RR	0
ST14-U	12.8
ST15-RR	0
ST16-RR	0

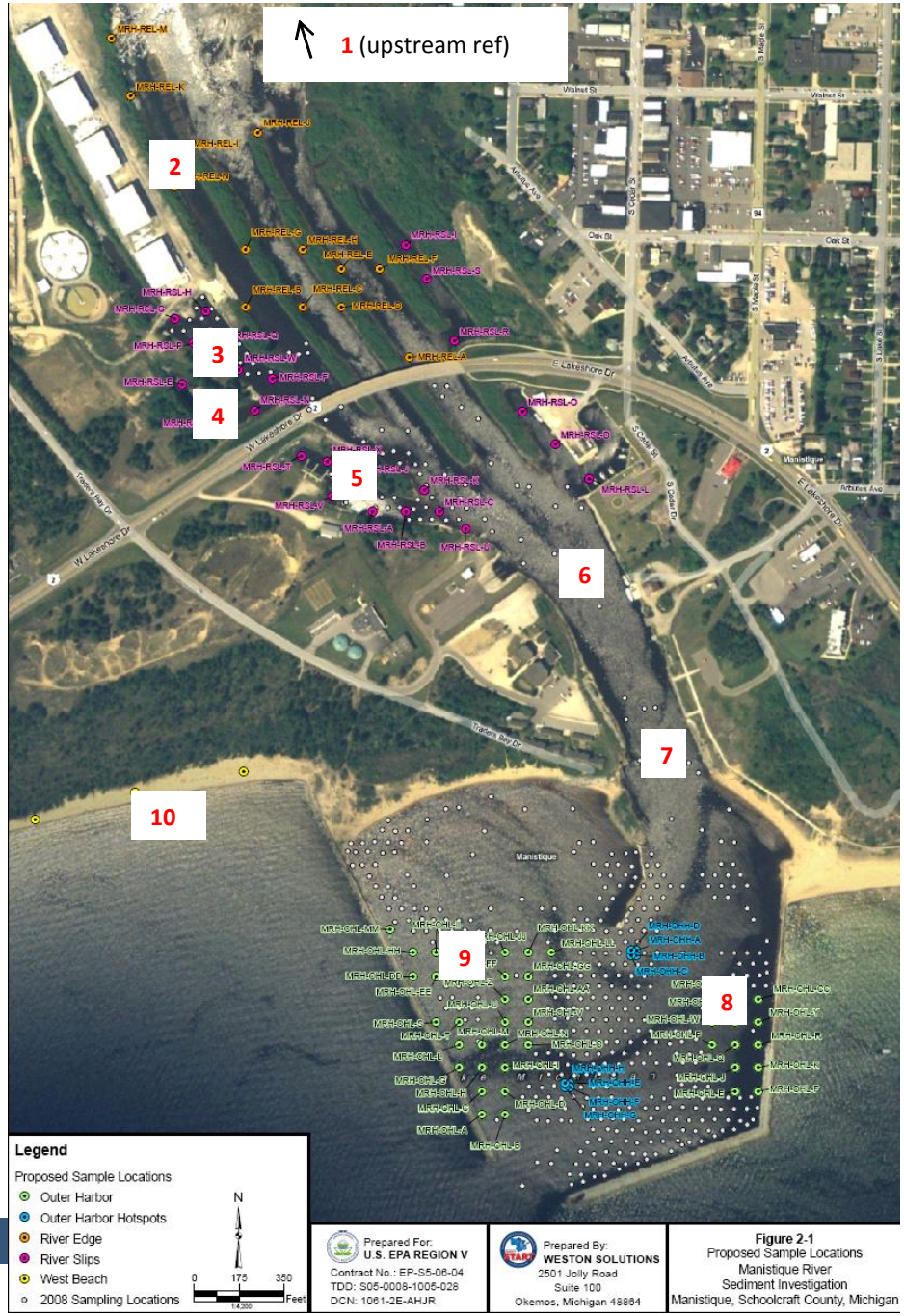
Courtesy Marc Mills

2012 Manistique AOC Source Tracking Polyethylene Devices (PEDs) - tPCBs



Stat Id	TOTAL PCB (ng/sample)
ST02-RL	63.0
ST02-RM	71.0
ST02-RR	698
ST03-RL	45.4
ST03-RM	812
ST03-RR	825
ST04-RL	80.0
ST04-RM	888
ST04-RR	923
ST05-RL	112
ST05-RM	540
ST05-RR	954
ST06-RL	103
ST06-RM	473
ST06-RR	1,500
ST07-RL	117
ST07-RM	367
ST07-RR	1,554
ST08-RL	100
ST08-RM	432
ST08-RR	1,093
ST09-RL	140
ST09-RM	459
ST09-RR	1,183
ST10-U	3,968
ST10-U	14,794
ST10-M	2,982
ST10-M	46,749
ST10-D	2,807
ST11-U	4,515
ST11-M	7,667
ST11-D	5,043
ST12-U	1,601
ST12-M	3,610
ST12-D	3,532
ST13-RL	149
ST13-RM	443
ST13-RR	1,604
ST14-U	3,340
ST14-M	19,580
ST14-D	9,971
ST15-RL	942
ST15-RM	861
ST15-RR	1,166
ST16-RL	1,220
ST16-RM	1,162
ST16-RR	1,251

Courtesy Marc Mills

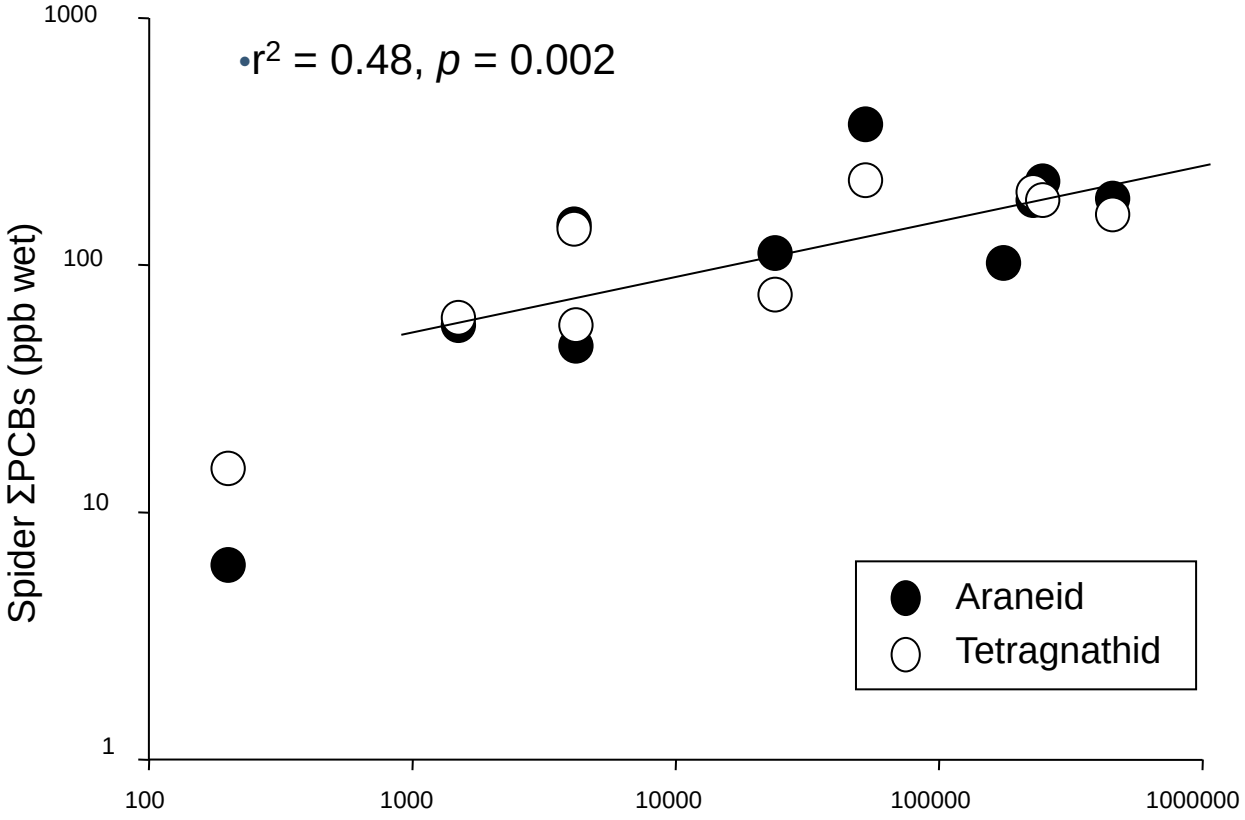


- Mosaic of aquatic habitats (vastly different chemistry & hydrology)
  - Backwater ("wetlands" connected to river)
  - Manistique River (blackwater)
  - Harbor (river/lake)
  - Lake Michigan
- Complex "river mouth/harbor" habitats typical of many AOCs

Courtesy David Walters

Sediment Vs. spider PCBs

Courtesy David Walters

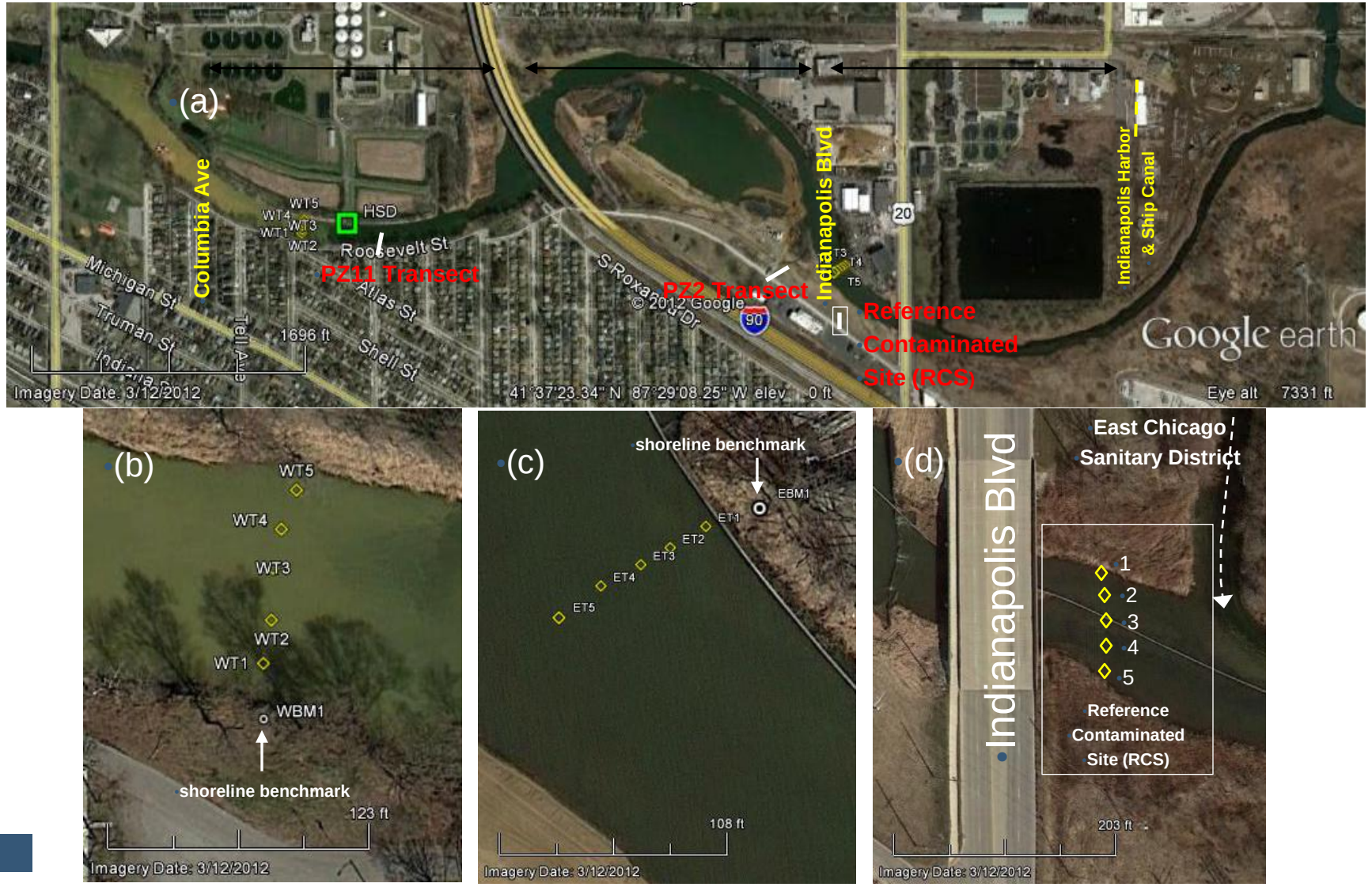


•Sediment $\Sigma PCBs_{TOC}$ ppb

West Branch Grand Calumet River Monitoring Cap Performance (PAHs)

EPA United States Environmental Protection Agency

Reach 2 **Reach 1** **Reference**



Layout of HD/MPS -Polyethylene Devices (PED) Deployments at Monitoring Transects

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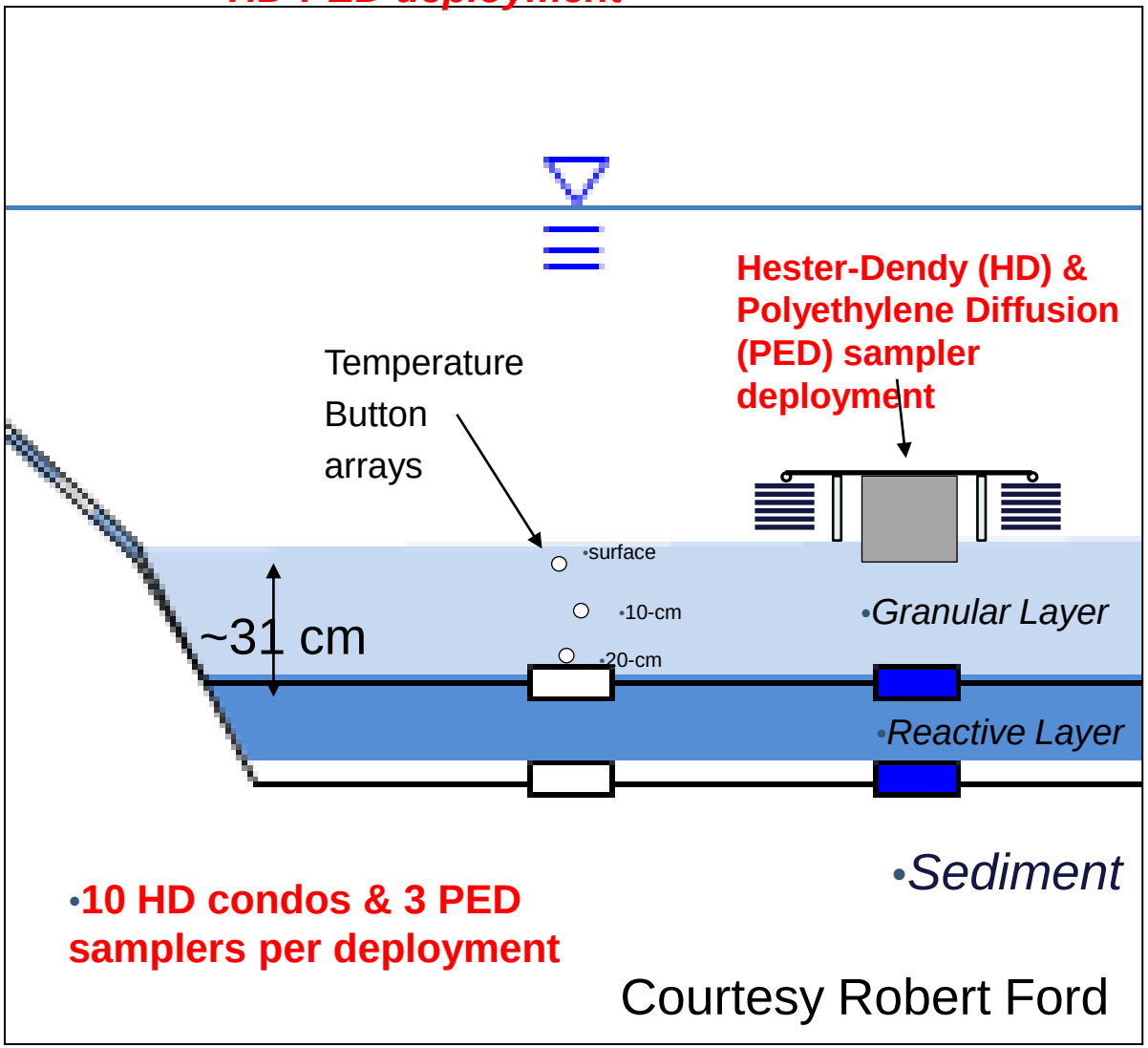
Each transect screen location had associated temperature button array & HD-PED deployment

PEDs

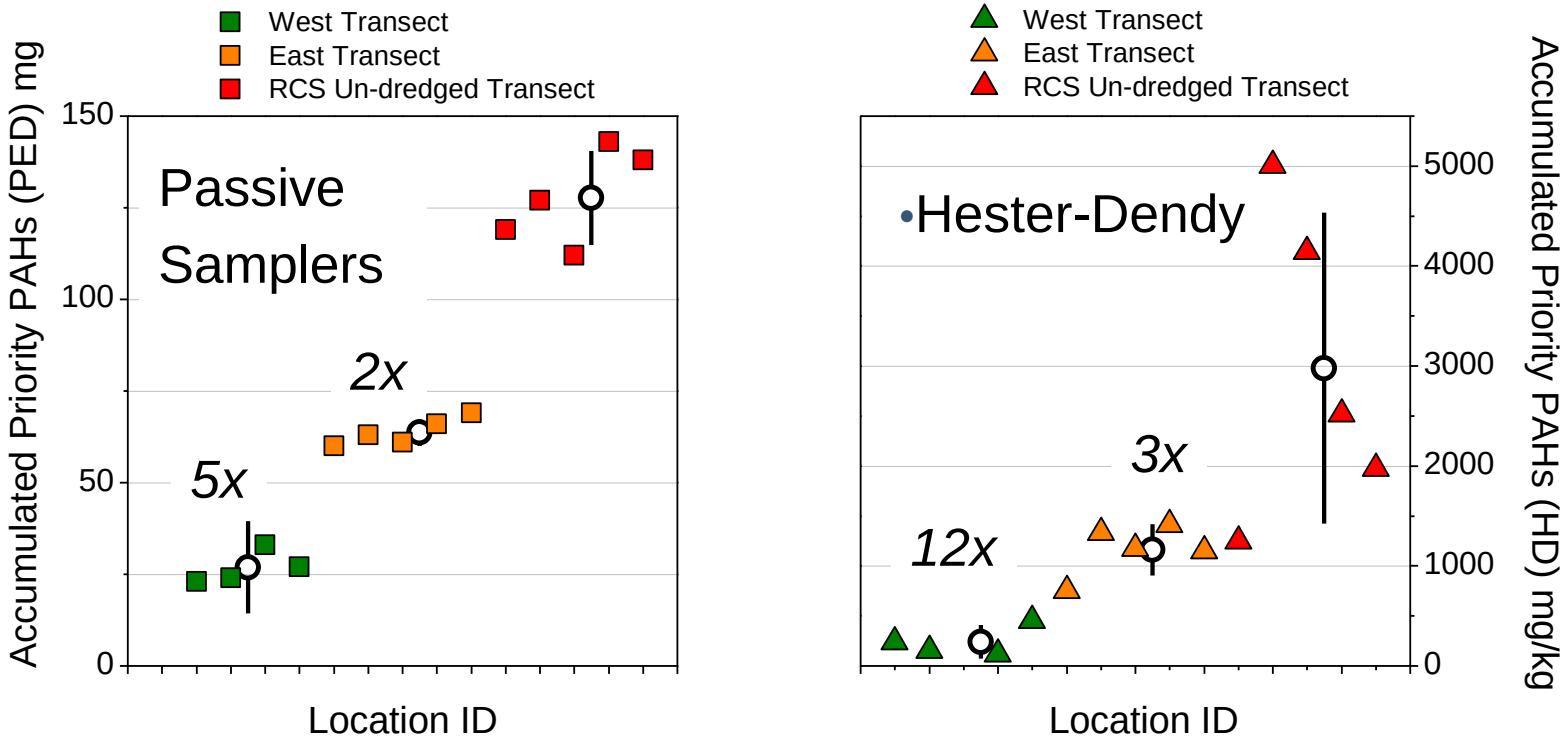
•Note: retrieval from RCS un-dredged reference site



Comparison of PAH Accumulation for Macrobenthos & Passive Samplers at ORD Transects and Un-dredged River Section

- **Passive sampler results indicate <u>average</u> relative improvement of 2-times for the east transect and ~5-times for the west transect.**

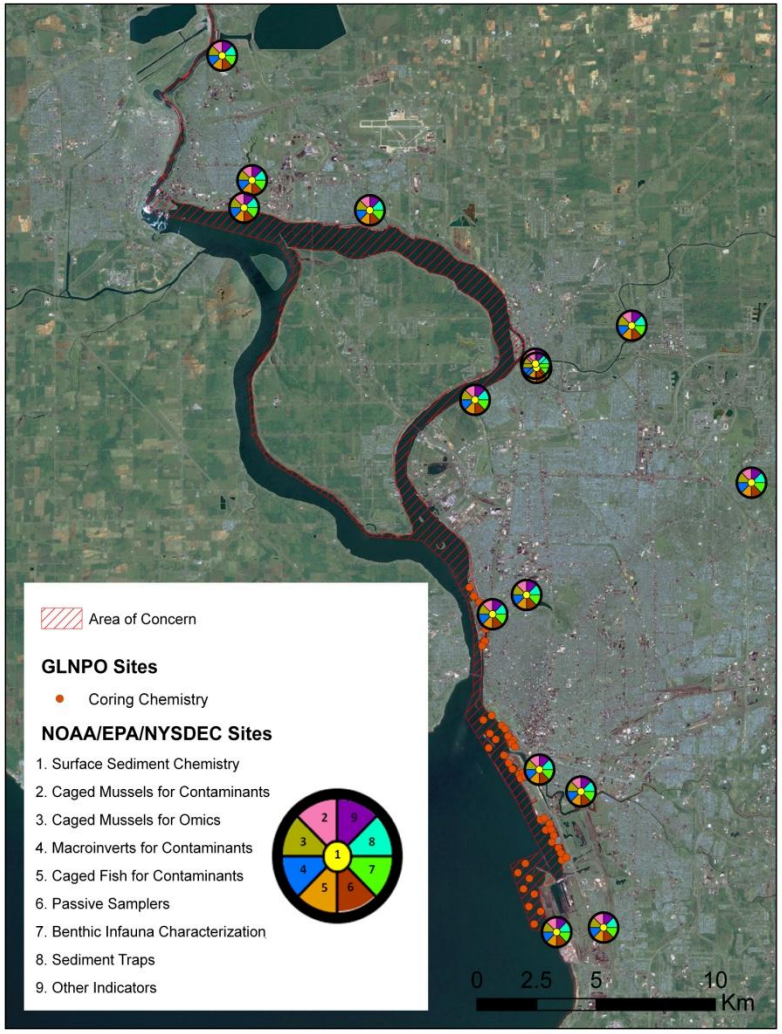
- **Hester-Dendy macrobenthos results indicate <u>average</u> relative improvement of ~3-times for the east transect and ~12-times for the west transect.**



•(Note: WT5 PED had low analysis recovery; WT3 HD insufficient sample)

2014 Niagara River AOC

Those in red were in exceedance of water criteria downstream, but not upstream, indicating a potential source within the watershed



DDT total	Mirex	Aluminum
p,p'-DDE	Chrysene/Triphenylene	Iron
p,p'-DDT	Total Chlordane	Mercury
Hexachlorobenzene	Dieldrin	Benzo(g,h,i)perylene
TCPCB	Benzo(b+k)fluoranthene	Benz(a)anthracene
Indeno(1,2,3-c,d)pyrene	Benzo(a)pyrene	

Courtesy Marc Mills/Kyle Fetters/Brian Crone

NOAA/EPA Indicator Toolbox

Indicator	Funding	Agency Lead	Deployment	Sampling	Revisit
Caged Mussels for contaminants	NOAA	NOAA	Late May	July	Sep
Caged Mussels for omics	NOAA	NOAA	Late May	July	Sep
Macroinvertebrates for contaminants (HD/MPS deployments)	**NOAA**	**EPA ORD**	**Late May**	**July**	**Sep**
Passive samplers Polyethylene Devices [PEDs])	**NOAA**	**EPA ORD**	**Late May**	**July**	**Sep**
Sediment chemistry (archive only; pending results)	**NOAA**	**EPA GLNPO/ORD**	**n/a**	**July**	
Benthic Infauna Characterization	NYSDEC	NYSDEC	n/a	July	
Sediment traps	**NOAA**	**EPA ORD**	**Late May**	**July**	**Sep**
Other indicators (Indigenous fish collection, sediment toxicity testing, genotoxicity assays, etc.)					

Courtesy Ed Johnson NOAA

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