Aquatic Ecology Research and Technology Development in East Fork Poplar Creek

Presentation to the
Oak Ridge Site Specific Advisory Board

June 8, 2016

Mark Peterson
Leader Aquatic Ecology Group
Environmental Sciences Division
Oak Ridge National Laboratory

Acknowledgements

Mercury Technology Development Project Team and Researchers:

- DOE OREM: Jason Darby, Elizabeth Phillips, Brian Henry, Laura Wilkerson
- UCOR/RSI: Charlie Mansfield, Jimmy Massey, Dan Macias, Mary Magleby, Carl Milligan
- ORNL: Scott Brooks, Melanie Mayes, Terry Mathews, Dave Watson, Alex Johs, John Dickson, Mark Peterson

Presentation Outline

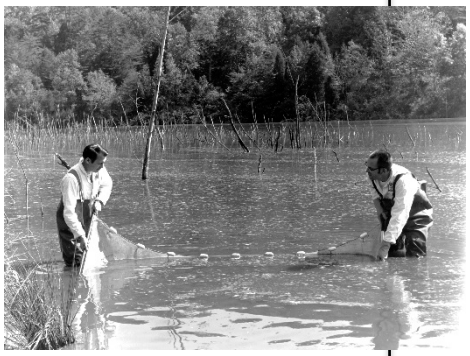
- ORNL aquatic ecology research
- Mercury in East Fork Poplar Creek
- Mercury technology development program
  - Strategy
  - Key findings to-date

OFFICE OF ENVIRONMENTAL MANAGEMENT

ORNL Aquatics Research has a Rich History in Oak Ridge

1940s 1950s 1960s 1970s 1980s 1990s 2000s 2010s

Seining White Oak Lake



(Clinton Laboratories) First surveys in the 1940s

Field Station, Clinch River

ORNL "Ecology Program" begins

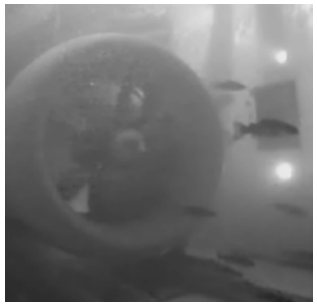
Walker Branch Watershed

50 Years of Stream Research

The Aquatic Ecology Laboratory is built

Biological Monitoring and Abatement Program (BMAP)

DOE WaterPower Program



Current Research Thrusts:

- Remediation/Restoration Science
- Technology Development
- Renewable Energy (hydropower, biofuel)
- Urban Dynamics Institute

The Aquatic Ecology Laboratory is a Premier Research Facility

- One of the few aquatic ecology research facilities in the southeast
- Focus on solutions to the US's most challenging energy-environmental problems
- Includes 9,000-square feet of floor space: outbuildings, extensive field research equipment, on-site research ponds, long-term Oak Ridge Reservation research sites
- A go-to place for aquatics research: 18 ORNL staff and ~20-30 subcontractors, students, and research visitors per year to the laboratory; major ORNL tour destination
- Strong ties to regional organizations and related missions (OREM, UCOR/RSI, CNS, TVA, UT, TTU, NEON Inc., CG Services, etc.)

Mercury is a Continuing Concern at East Fork Poplar Creek

Timeline

1953-1983: It is estimated between 239,000 to 470,000 lbs of mercury (Hg) were released from Y-12 into East Fork Poplar Creek

1992-1995: Remedial Investigation (RI), RI Addendum, Feasibility Study, and Record of Decision completed for floodplain (not the creek or banks); the remedy selected focused on human health ingestion of soils and set a remediation goal of 400 ppm

1996-1997: 34,220 m^3 of contaminated soil (>400 ppm mercury) removed from floodplain

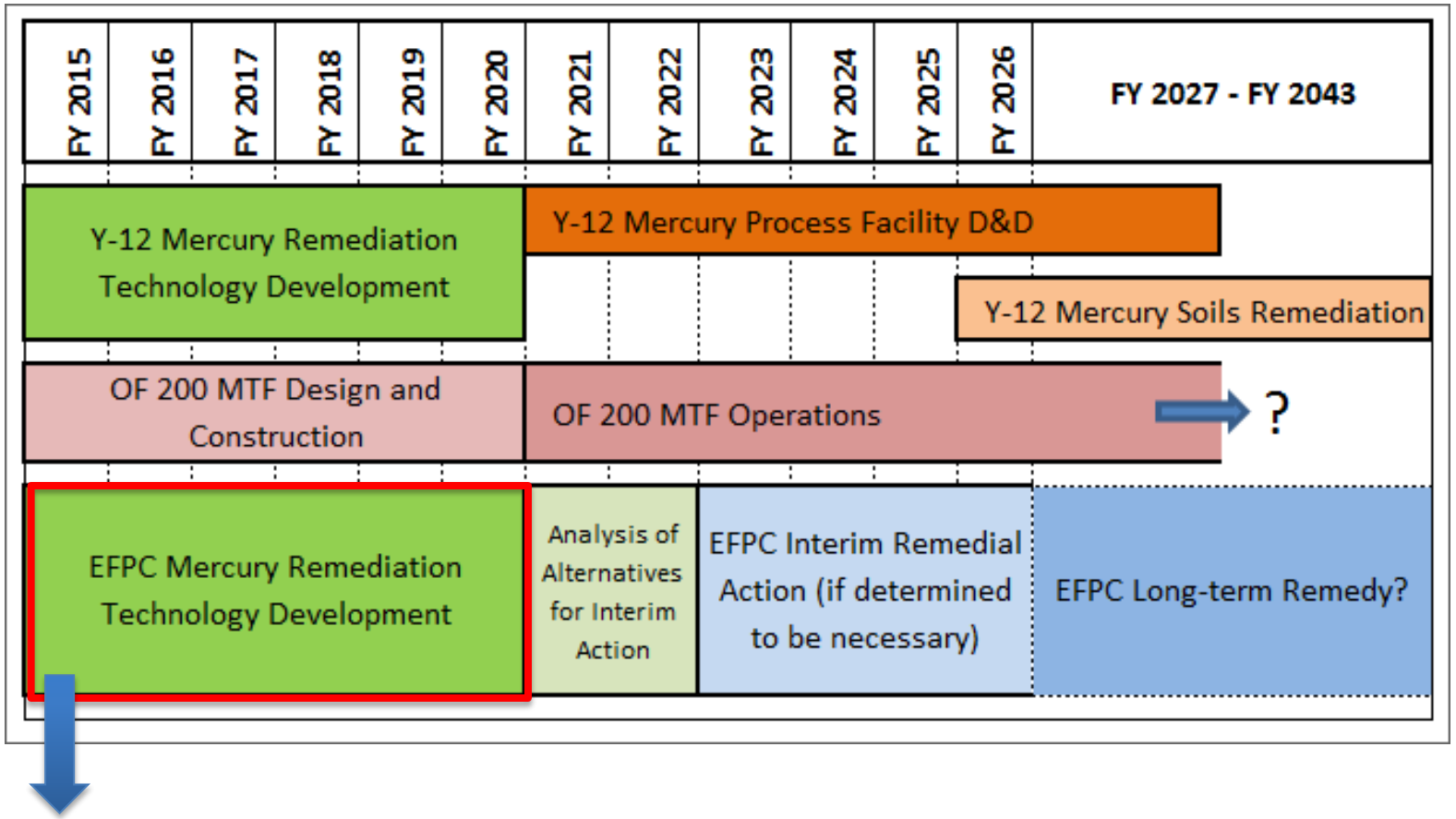
1998-present: Focus on remedial and abatement actions at Y-12

2013-2014: Strategic planning with regulators identified the role of downstream sources of mercury to the stream environment and the importance of research and technology development in the mercury remediation program

Current/Future for OREM Mercury:

1) Design and construction of new mercury treatment facility at Y-12
2) Research and technology development in lower East Fork, leading to an alternative evaluation in the 2020s

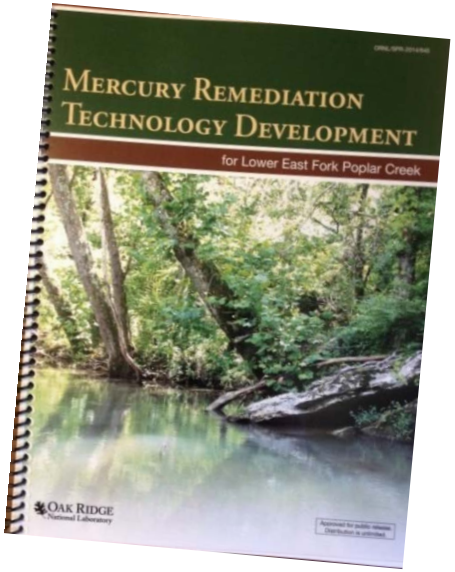
Mercury Technology Development and Mercury Cleanup Activities will Continue for Many Years



Project start, August 2014

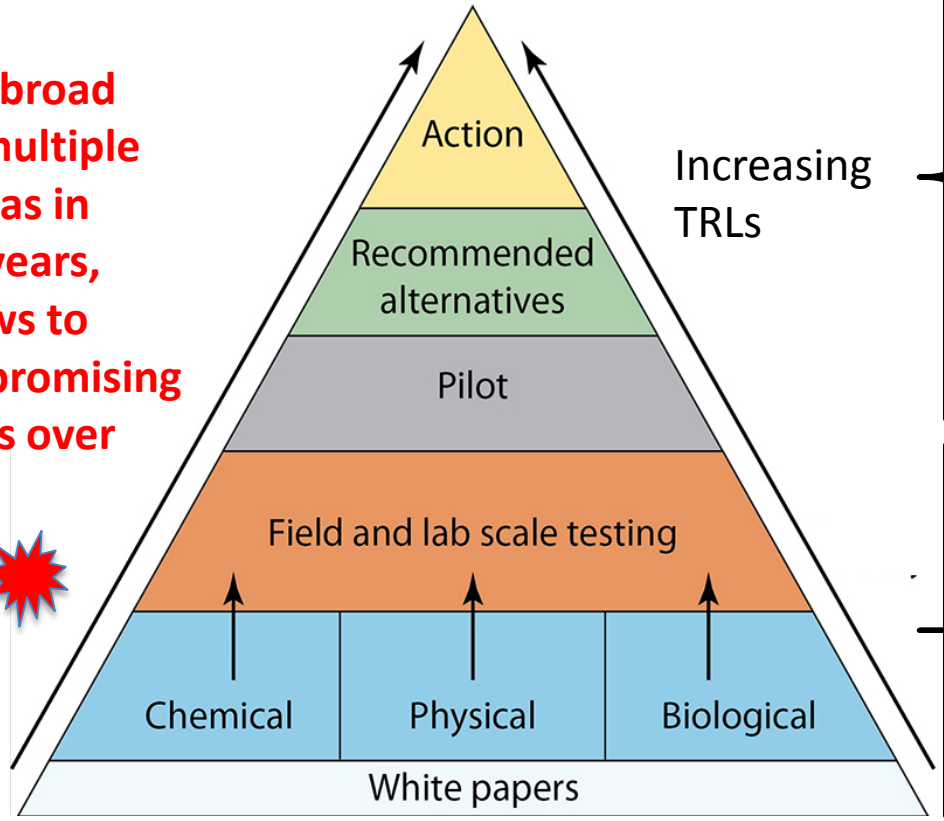
A Plan for Mercury Technology Development has been Designed for Lower East Fork Poplar Creek

- Follows Oak Ridge mercury strategy consistent with priorities and timeline of remediation activities in Oak Ridge
- Recognizes watershed scale and complexity of the mercury problem
- Developed based on extensive literature review of the state of mercury remediation science and technology development, as well as on-site data
- Goal to develop new approaches and technologies to remediate mercury in East Fork Poplar Creek while preserving or enhancing natural resources
- Regulatory Targets:
  - Reduce mercury flux
  - Reduce mercury concentration in water
  - Reduce mercury in fish



A Pyramid Approach will be Utilized for East Fork Poplar Creek Technology Development

Starts broad with multiple TD ideas in early years, narrows to most promising actions over time

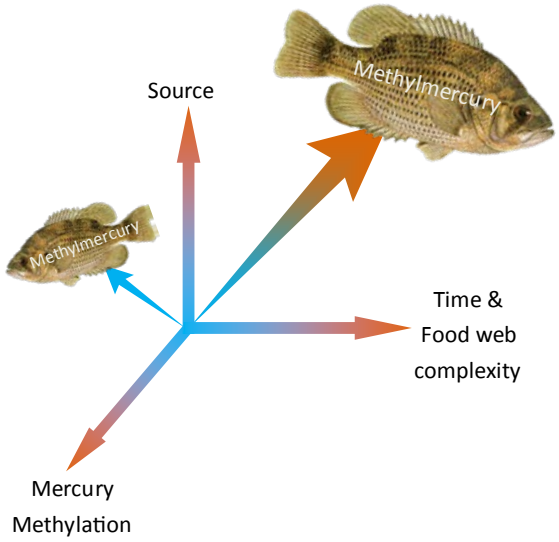


Increasing TRLs

Technology Readiness Levels

- TRL 7-9: System commissioning and operations
- TRL 5-6: Lab or field engineering/pilot, larger scale evaluation
- TRL 2-4: Field and lab batch or bucket testing evaluation
- TRL 1-2: Paper reviews, study site characterization

There are Three Major Project Tasks



Three key factors determine the level of mercury contamination in fish—the amount of inorganic mercury available to an ecosystem, the conversion of inorganic mercury to methylmercury, and the bioaccumulation of methylmercury through the food web.

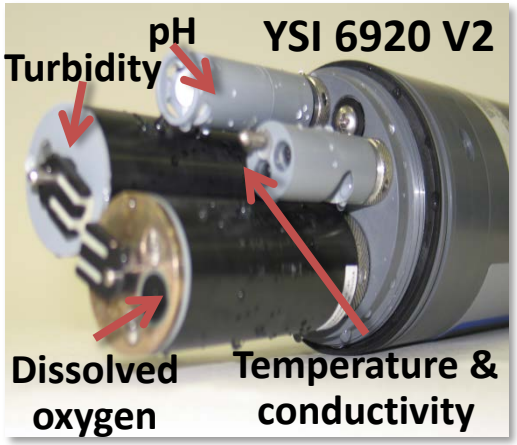
-USGS Circular 1395 (2014)

Tasks:	*Goals/Potential Benefits:*
Soil and Groundwater Source Control	Primary benefit is decreased mercury source inputs, **flux**
Water Chemistry and Sediment Manipulation	Primary benefit is decreased mercury **concentration and methylation**
Ecological Manipulation	Primary benefit is decreased mercury **bioaccumulation**

Understanding the System is Essential to Developing the Best Technological Solutions

Evaluating bank mercury and soil erosion

Understanding water chemistry and flow changes



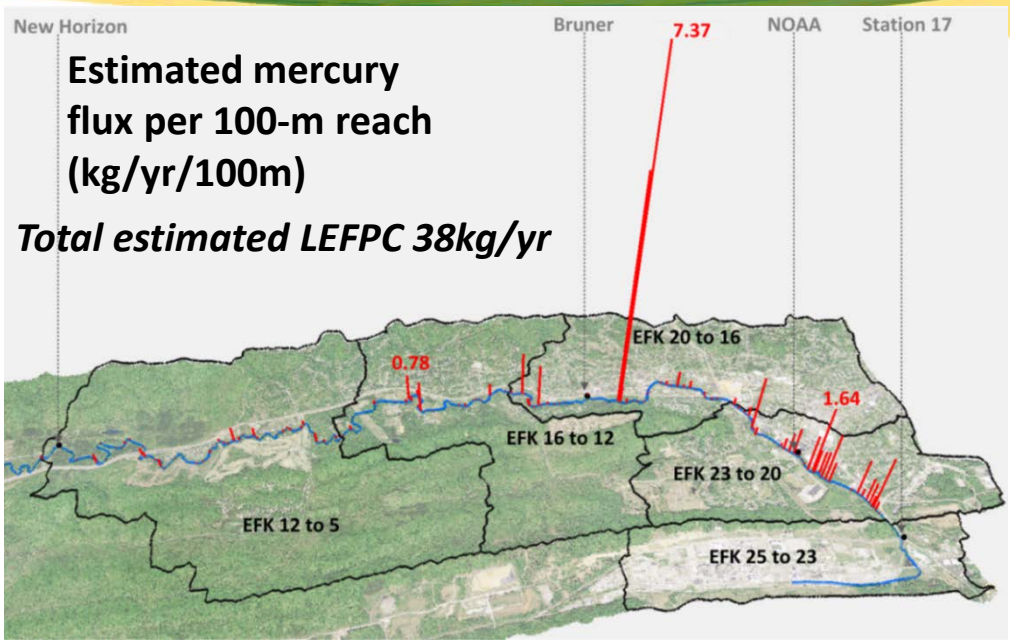
Investigating methyl mercury in biota

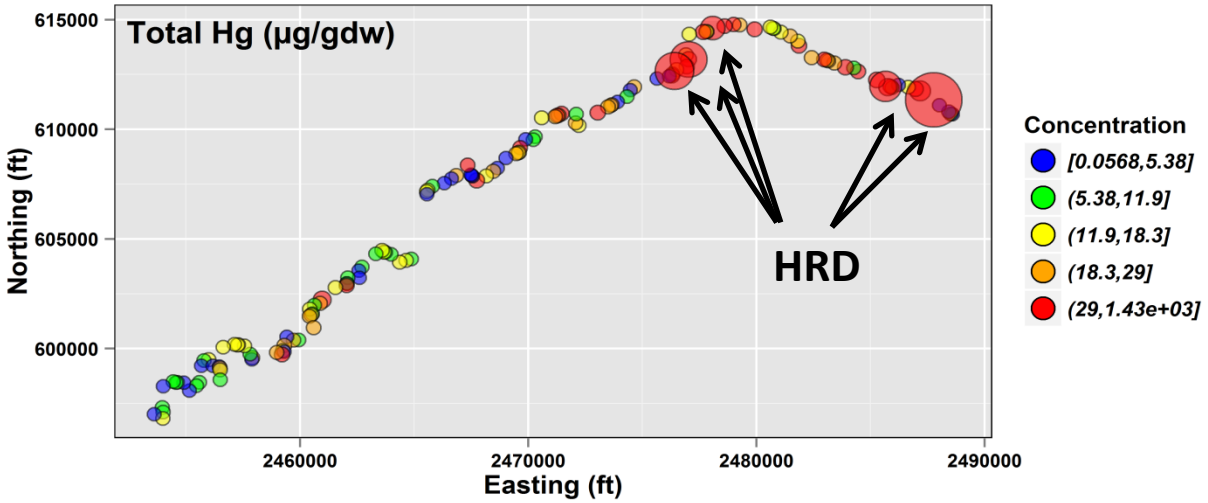
There have been Several Key Findings To Date

Soil and Groundwater Source Control

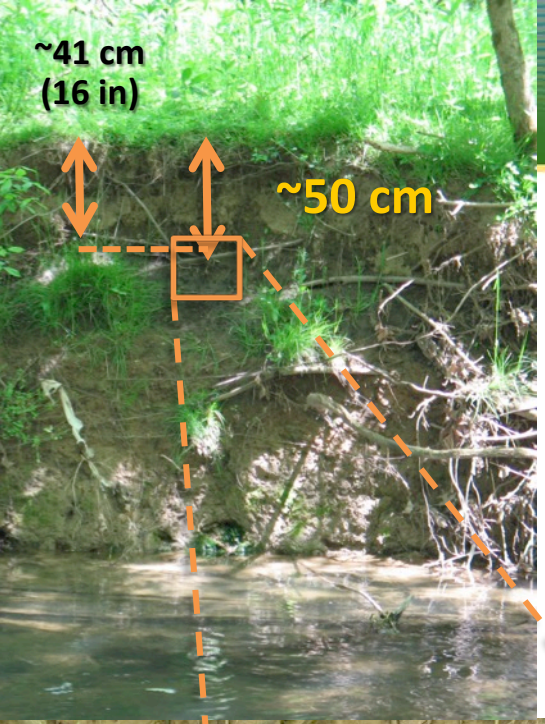
Role of Stream Banks

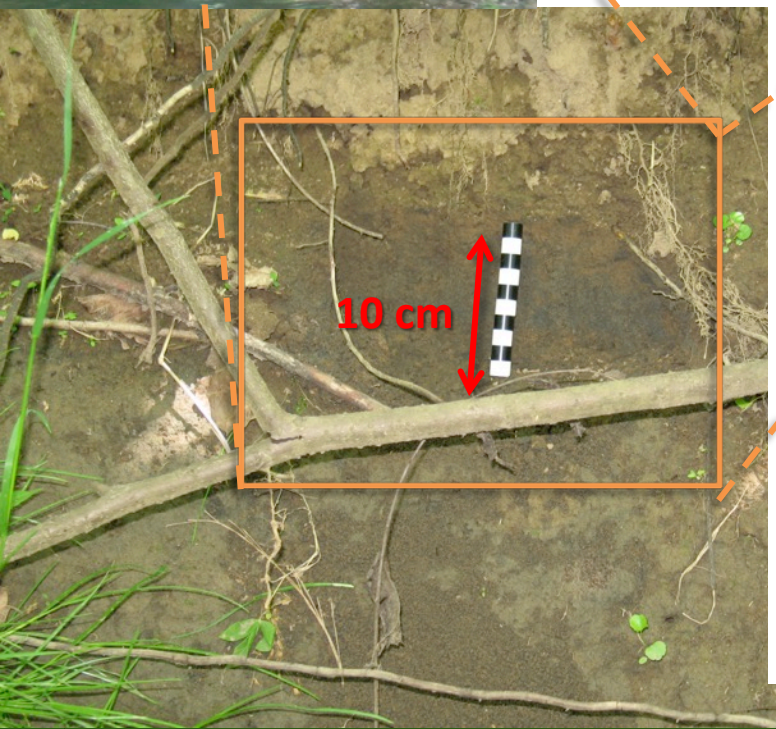
- Erosion estimates and mercury sampling provided first detailed estimate of bank mercury flux
- Highest concentrations and fluxes in the upper section of creek
- Bank soils are a major source of mercury to the creek
- Discovered and described a historical release deposit (HRD) with high mercury concentrations

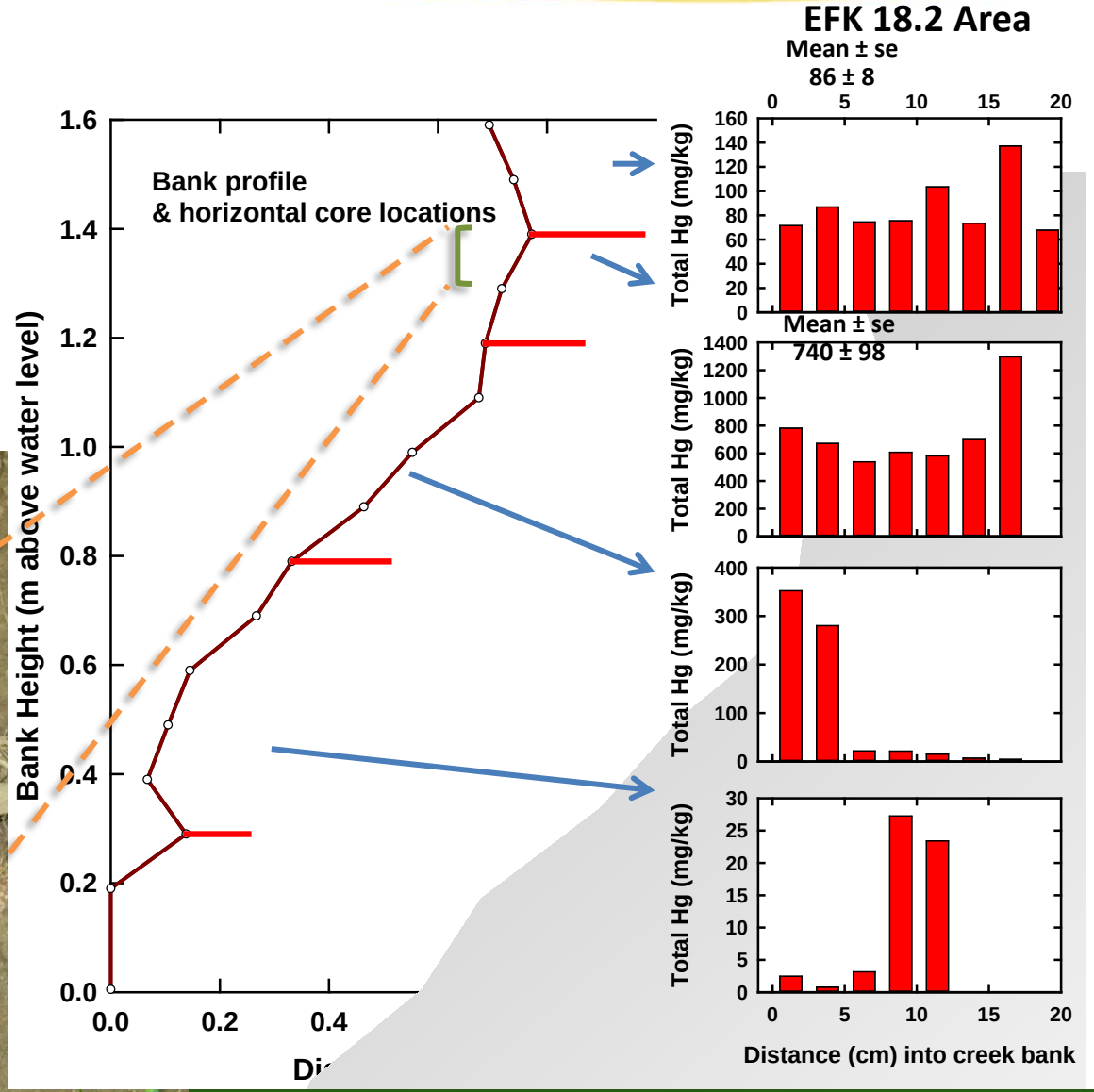




The Bank Soil Results are Highly Variable; Technology Solutions May be Best Targeted to the Highest Flux Areas

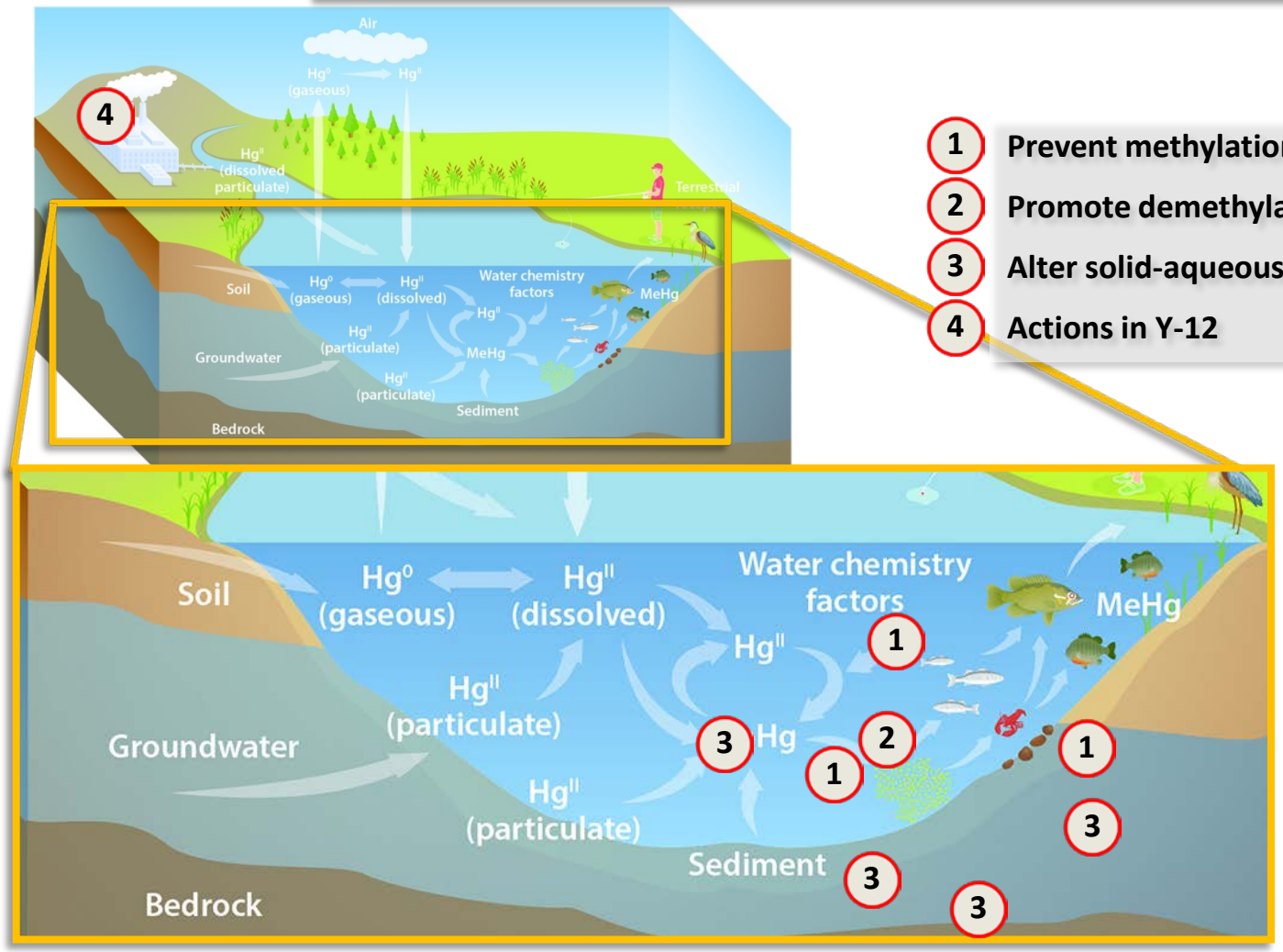






There are Many Factors Involved in Evaluating Water Chemistry and Sediment Manipulation

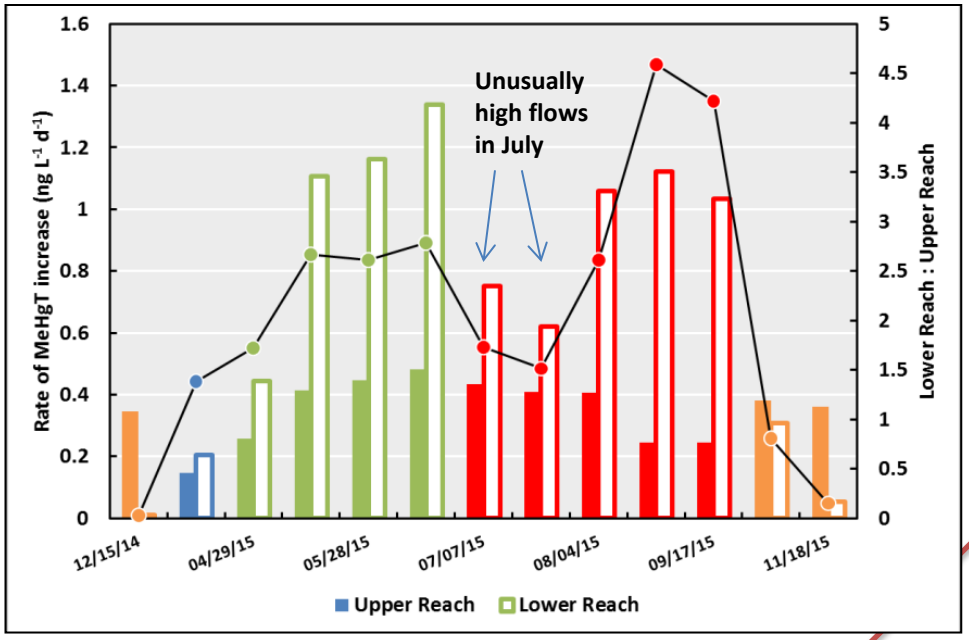
Evaluations of potential water chemistry manipulations in the creek will depend on a thorough understanding of current stream chemistry conditions



1. Prevent methylation
2. Promote demethylation
3. Alter solid-aqueous partitioning
4. Actions in Y-12

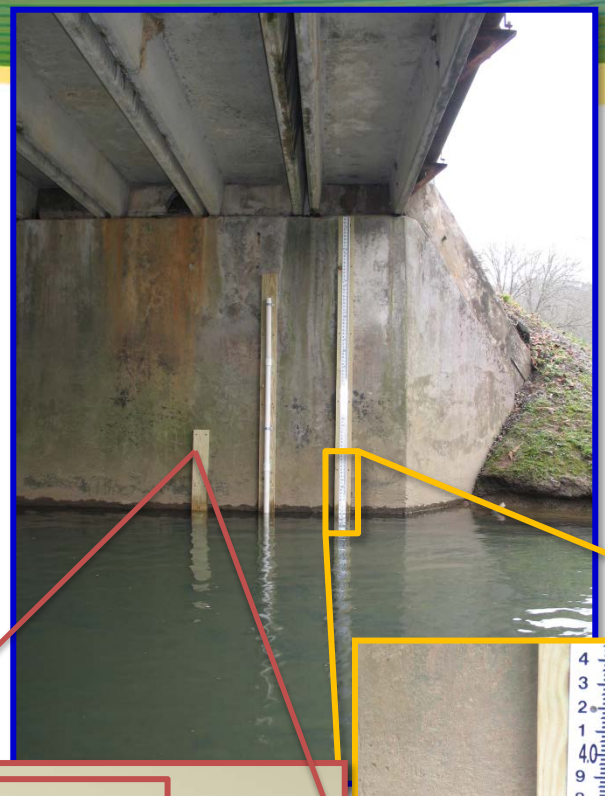
New Gauging/Monitoring Activity Enables Comparison of Upper Versus Lower Reaches of Lower East Fork Poplar Creek

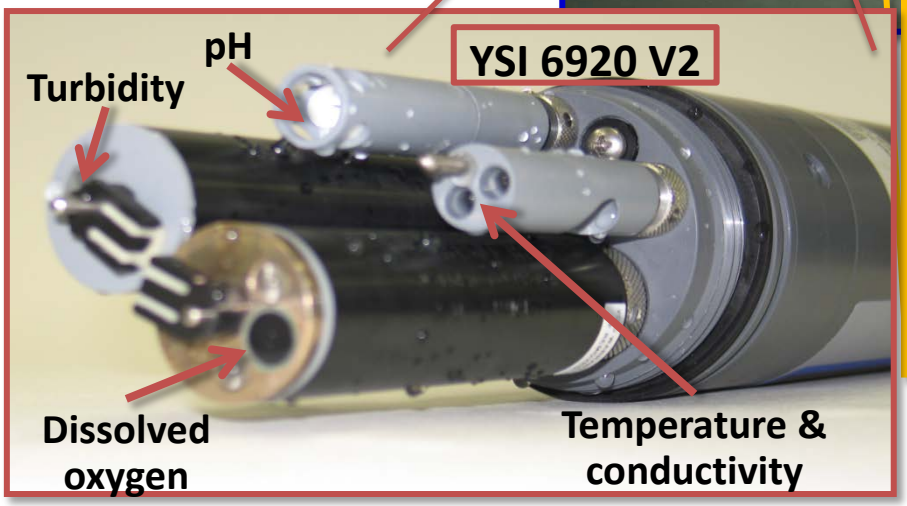
- **Rate of Methyl Hg increase in lower East Fork**



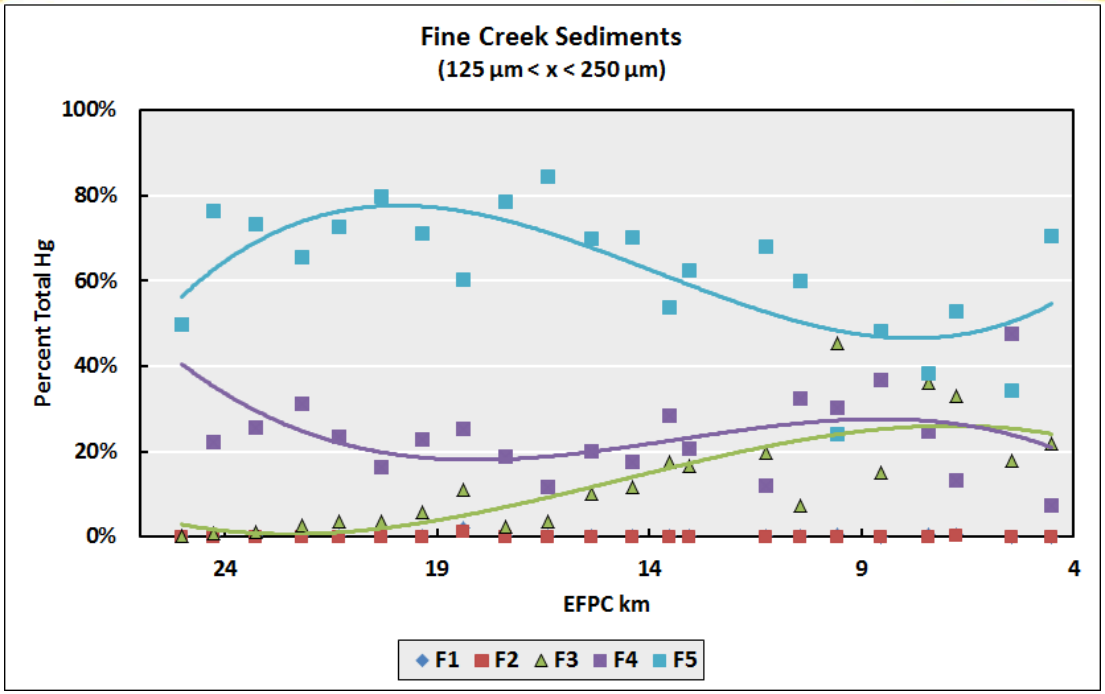
Orange = Autumn
Blue = Winter
Green = Spring
Red = Summer

Filled bars = upper reach (EFK23.4-EFK16.2
Open bars = lower reach (EFK16.2 – EFK 5.4)





Mercury Extractability in Fine-Grained Creek Sediments Changes Systematically Downstream



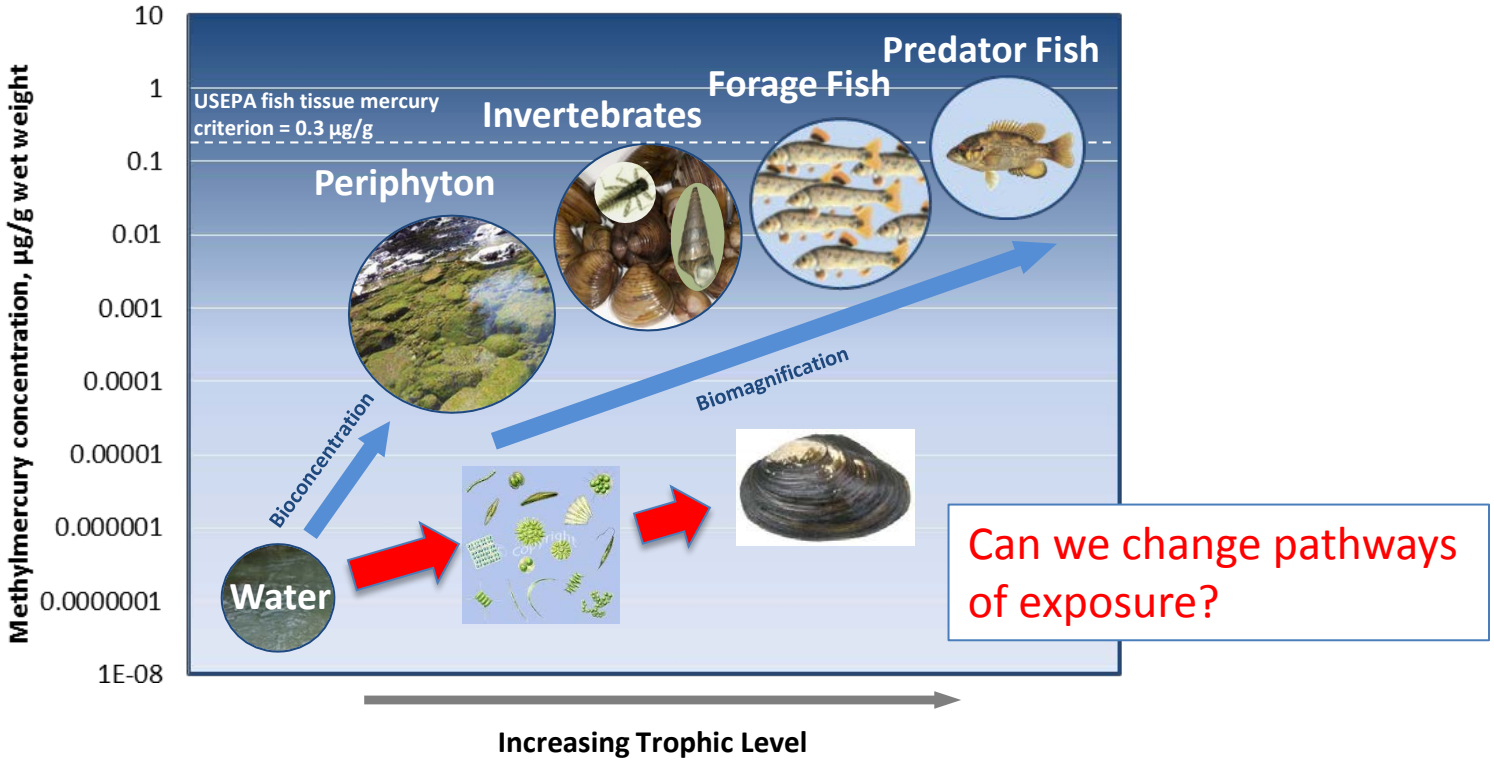
Sequential Extraction Analyses

Fraction	Composition
F1	Anaerobic DIW
F2	HCl + Acetic acid (pH 2)
F3	1 M KOH
F4	12 N HNO_3
F5	Aqua Regia (HCl: HNO_3; 10:3)

- >97% of mercury extracted only in more chemically aggressive solutions (F3+F4+F5)
- Systematic shift in fractions downstream
  - More extracted in F3 at the expense of F5
- **Implication:** Mercury extracted in F3 fraction most strongly correlated with methylation potential (Bloom, 2003)

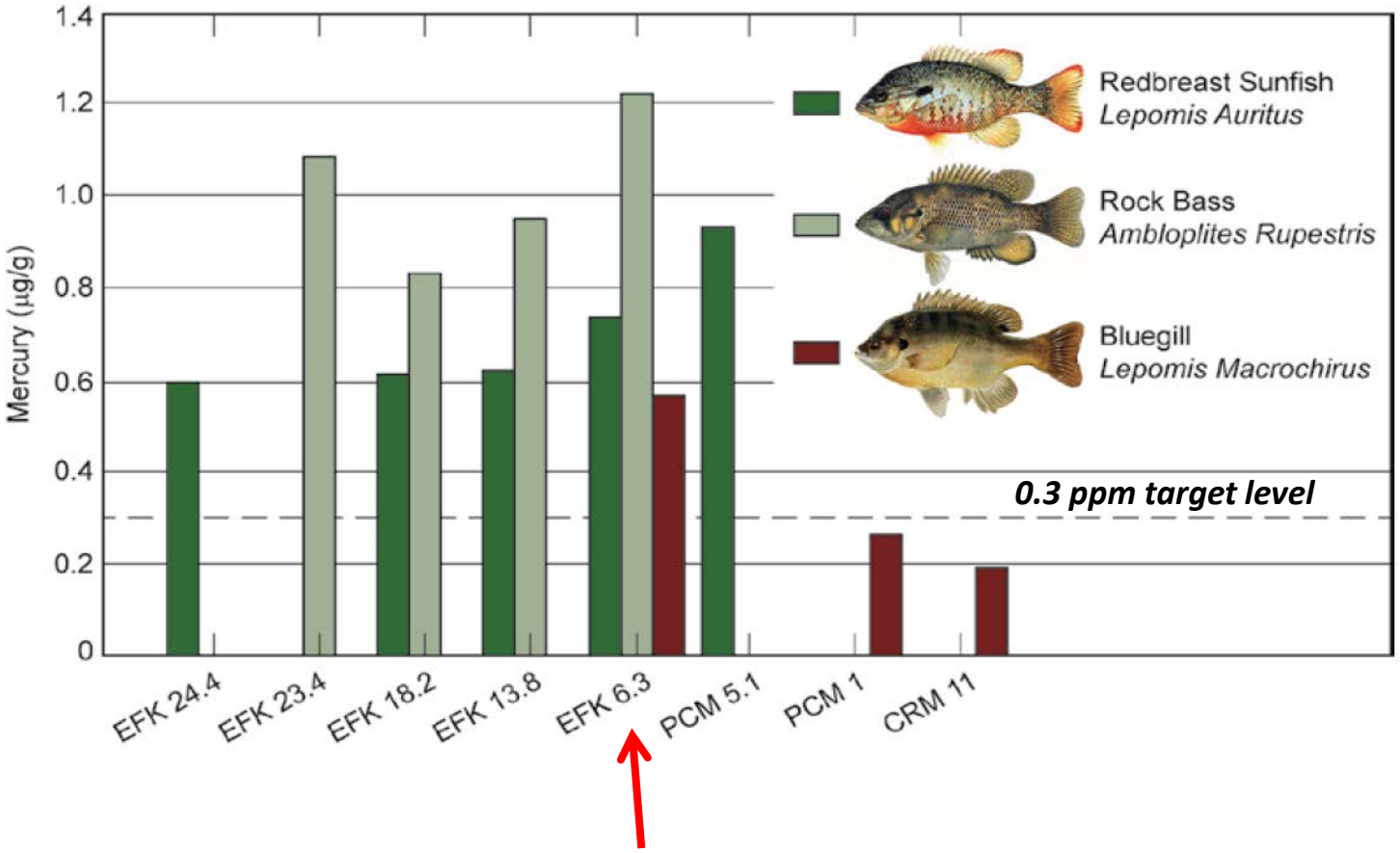
Food Chains Make a Difference in Mercury Bioaccumulation

- Longer food chains can increase mercury bioaccumulation
- Each organism has different bioaccumulation potential
- Greatest biomagnification step low in the food chain
- Recent finding: algae a major contributor to mercury methylation

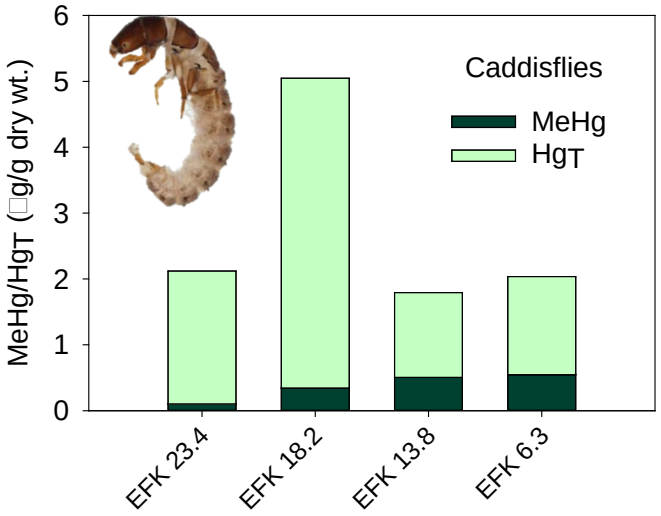


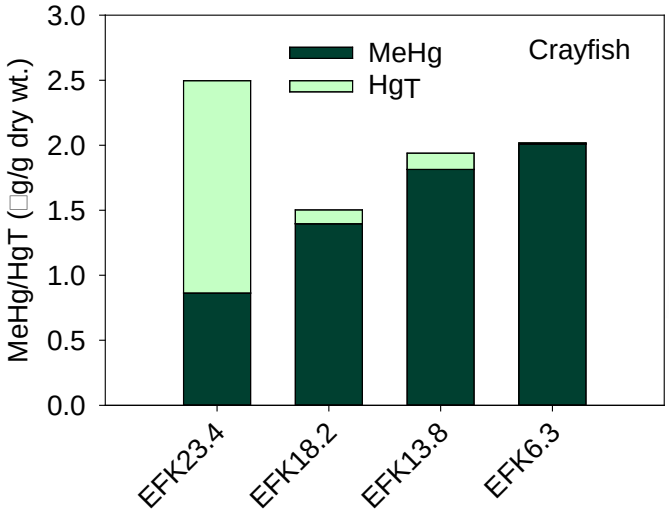
There are Significant Differences in Fish Species Bioaccumulation

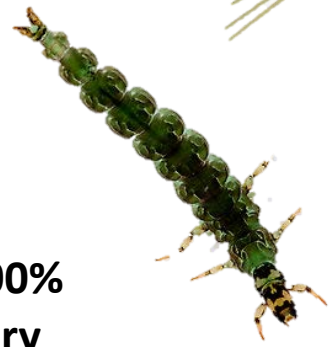
- East Fork is now dominated by rock bass, a higher trophic level fish
- Will redbreast dominate with flow augmentation off?



Percent Methylmercury Varies by Invertebrate Species







Bivalves near 100% inorganic mercury

The Next Step is to Develop Mercury Control Technologies

Soil and Groundwater Source Control

Soil and sediment sorbent studies

Water Chemistry and Sediment Manipulation

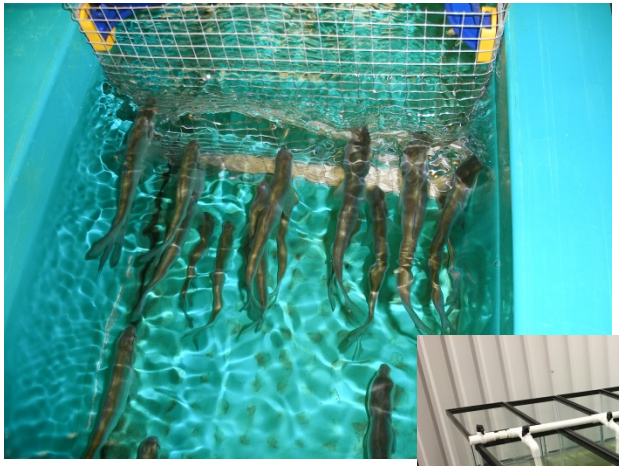
Decreasing dissolved mercury through chlorine removal

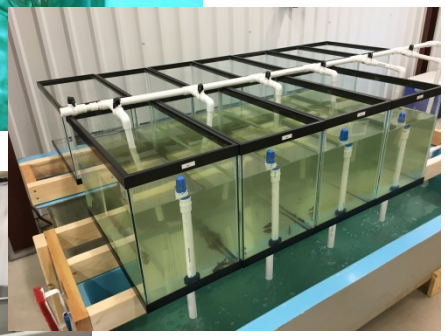
Ecological Manipulation

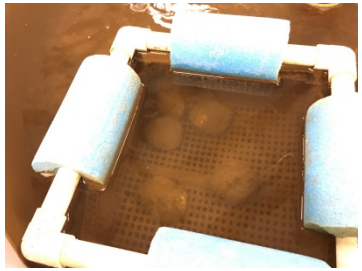
Investigating potential for reintroduction of mussels to decrease mercury in particles/algae

Developing Technologies Includes the Proposed East Fork Poplar Creek Field Research Station

- Near-creek research facility provides a desirable flow-through system that can evaluate approaches and technologies to decrease in-stream mercury
- Examples include sorbents, manipulations of water or sediment chemistry, or biological changes
- Site in lower East Fork Poplar Creek preferred because of desirable chemistry
- Important for scale-up prior to pilot scale demonstrations
- ORNL research emphasizes **environmentally friendly solutions**







Water Quality "Good News" Stories

Radio

5/1/2015; WUOT Interview

Invertebrates rebound

Focus on recovery of stream invertebrate populations on the Oak Ridge Reservation

Web video

6/12/2015, BBC Horizons

Episode 6: Pollution Solutions; Reversing the effects of pollution

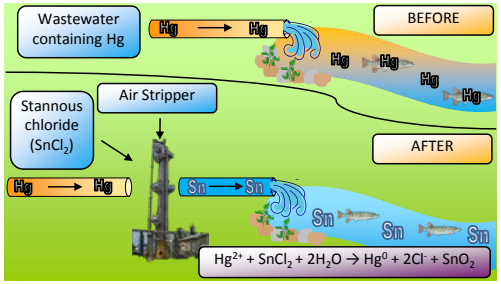
Finding science-based solutions for addressing global mercury pollution

Open Literature

Fall 2015

Chemosphere

Water chemistry manipulation applied successfully at the Savannah River site.



TV

7/31/2015

WBIR Interview

Students find a future through ORNL jobs

- UT and Duke students conduct studies to improve urban water bodies

Newspaper

8/2/2015, KNS

Pond makeover in Oak Ridge reduces risks, adds beauty

Status of innovative remediation project

Future:

- City of Oak Ridge water storage tanks
- Y-12 Mercury Treatment Facility