

Long-term Monitoring and Restoration Effectiveness

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Monitoring = *Collection and analysis of repeated measurements to evaluate changes in condition and progress toward meeting a management objective*

U.S. EPA 2004

National Long-Term Monitoring Programs

- Assess long-term status and trends

EPA's EMAP <http://www.epa.gov/emap/>

USGS NAQWA <http://water.usgs.gov/nawqa/>

- Basic ecological research

NSF LTER <http://www.lternet.edu/>

Programs Designed to Quantify Remediation Effectiveness

- U.S. EPA 2005. Remedial Action and Long-Term Monitoring. In Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. U.S. EPA EPA-540-R-05-012
- Framework for Long-Term Monitoring of Hazardous Substances at Sediment Sites, 2009. Association of State and Territorial Solid Waste Management Officials.
- Long-Term Monitoring Strategies For Contaminated Sediment Management. 2010. Space and Naval Warfare Systems Center Pacific and ENVIRON International Corporation.

Criticism of Monitoring

16 October 1964, Volume 146, Number 3642

SCIENCE

Strong Inference

Certain systematic methods of scientific thinking
may produce much more rapid progress than others.

John R. Platt

*We speak piously of taking small measurements and making small studies that will **add another brick to the temple of science**. However, most of these bricks simply lie around the brickyard.*

J.R. Platt, 1964

Criticisms of Long-Term Monitoring Programs

- Average duration of “long-term” monitoring in aquatic ecosystems is 9 y
(Jackson & Füreder 2006)
- Meta-Analysis: Failure to observe recovery attributed to short duration of monitoring
(Jones & Schmitz, 2009)
- Assessment of restoration progress not possible with the *piecemeal* information currently available
(Bernhardt 2005)
- Insufficient post-remediation data (NRC 2008)

Inability to quantify restoration effectiveness due to:

- Failure to set monitoring goals as testable hypotheses (e.g., remediation will reduce Hg in fish)
- Failure to adequately characterize baseline conditions
→ cannot employ inferential statistics (BACI design)
- Failure to establish specific decision rules
→ if ...then statements indicating when to stop or modify
- Failure to integrate physical, chemical and biological measures → weight of evidence approaches

How can we avoid making these mistakes?

A few basic questions:

1. What is the purpose of the monitoring program?
→ **hypothesis driven**
2. What are the specific variables to be measured?
3. How often should monitoring take place, and how long should it continue?
4. What factors, in addition to remediation, will influence the results?

5. What are the most appropriate statistical methods for analyzing the data?
6. Who is responsible for reviewing the data and what are the triggers for identifying important trends?
7. How will the results be communicated to the public and who is responsible for doing this?
(searchable, electronic databases?)

A Long-Term, Multitrophic Level Study to Assess Pulp and Paper Mill Effluent Effects on Aquatic Communities in Four US Receiving Waters: Background and Status

Timothy J Hall,† Robert P Fisher,‡ John H Rodgers Jr,§ G Wayne Minshall,|| Wayne G Landis,#
Tibor G Kovacs,†† Barry K Firth,‡‡ Monique G Dubé,§§ Thomas L Deardorff,|||| and Dennis L Borton##*

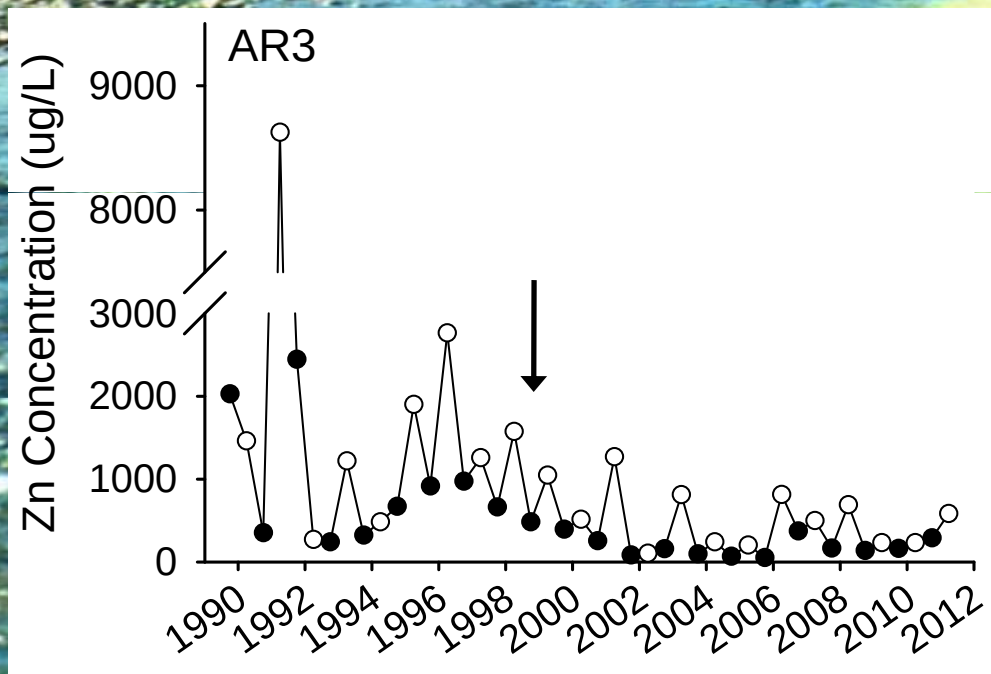
- Series of 8 papers published in IEAM in 2009
- 8 year study of 4 watersheds (OR, PA, MS)
- Goals: assess current status and quantify responses to pulp mill process changes → experiment
- Hypothesis driven (ecological risk assessment framework)
- Adaptive management process
- Integrated field assessments with short term lab experiments

Quantifying restoration success and recovery in a metal-polluted stream: a 17-year assessment of physicochemical and biological responses

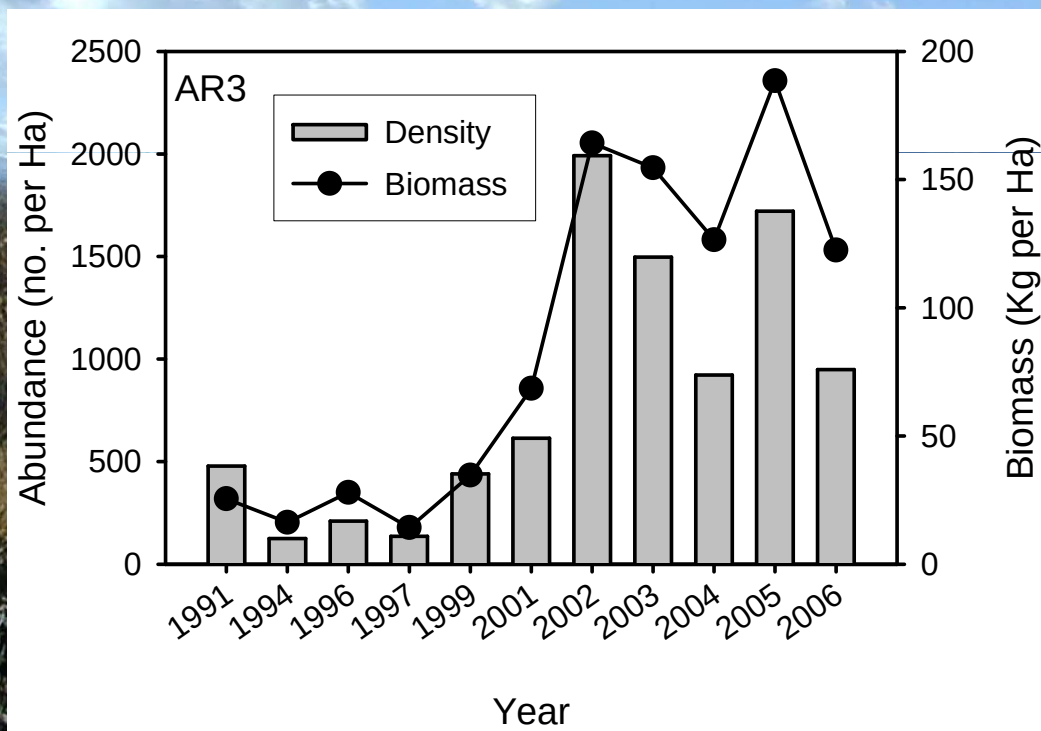
William H. Clements^{1*}, Nicole K. M. Vieira² and Stanley E. Church³

- Long-term (1989–2012) record of chemical, physical, biological data
- All data collected by same investigator
→ consistent methods
- Evaluated response to restoration treatments (BACI)
- Influence of long-term climatic changes

Arkansas River, CO (1989-2012)

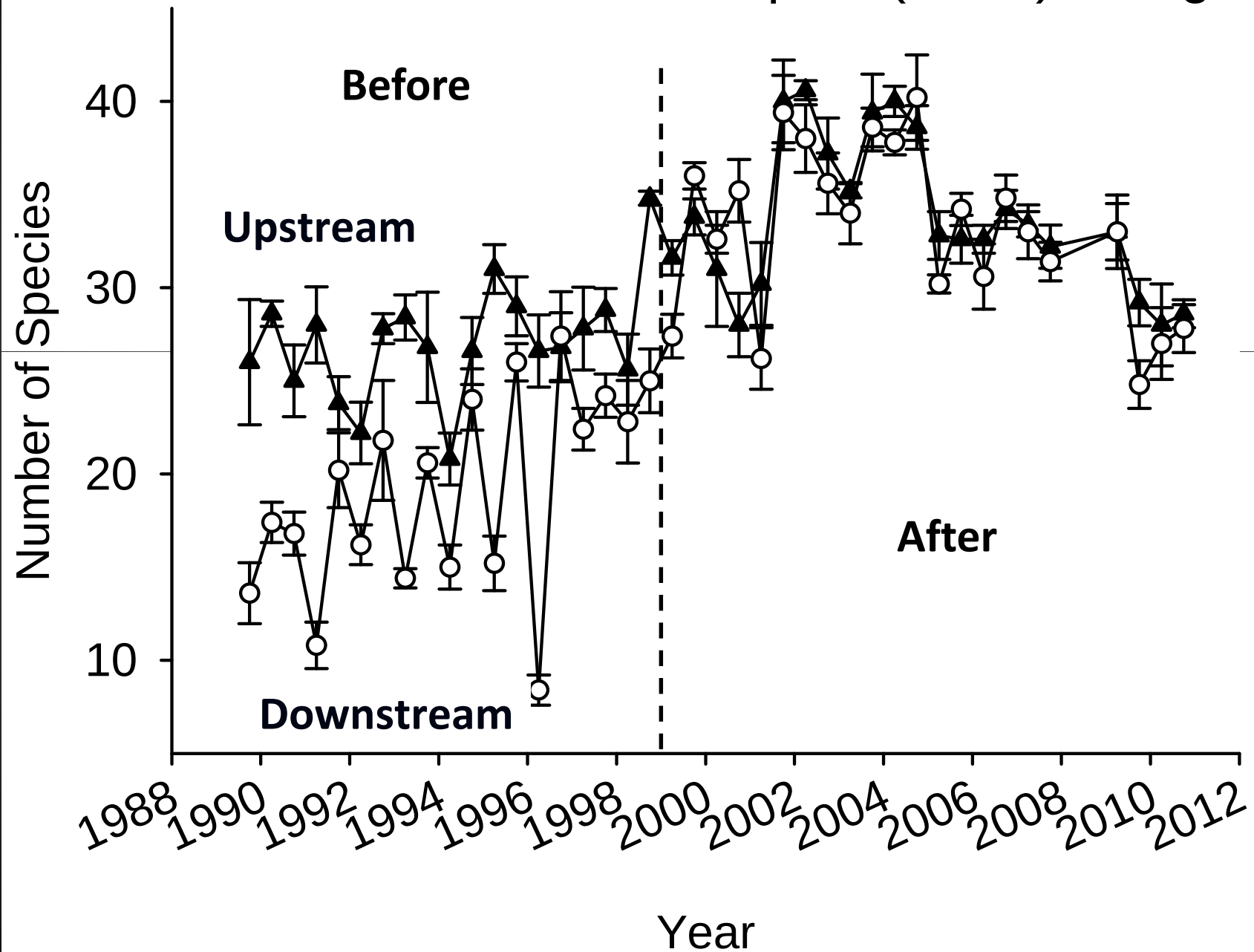


Hypothesis: Remediation will improve water quality, macroinvertebrate communities and brown trout populations

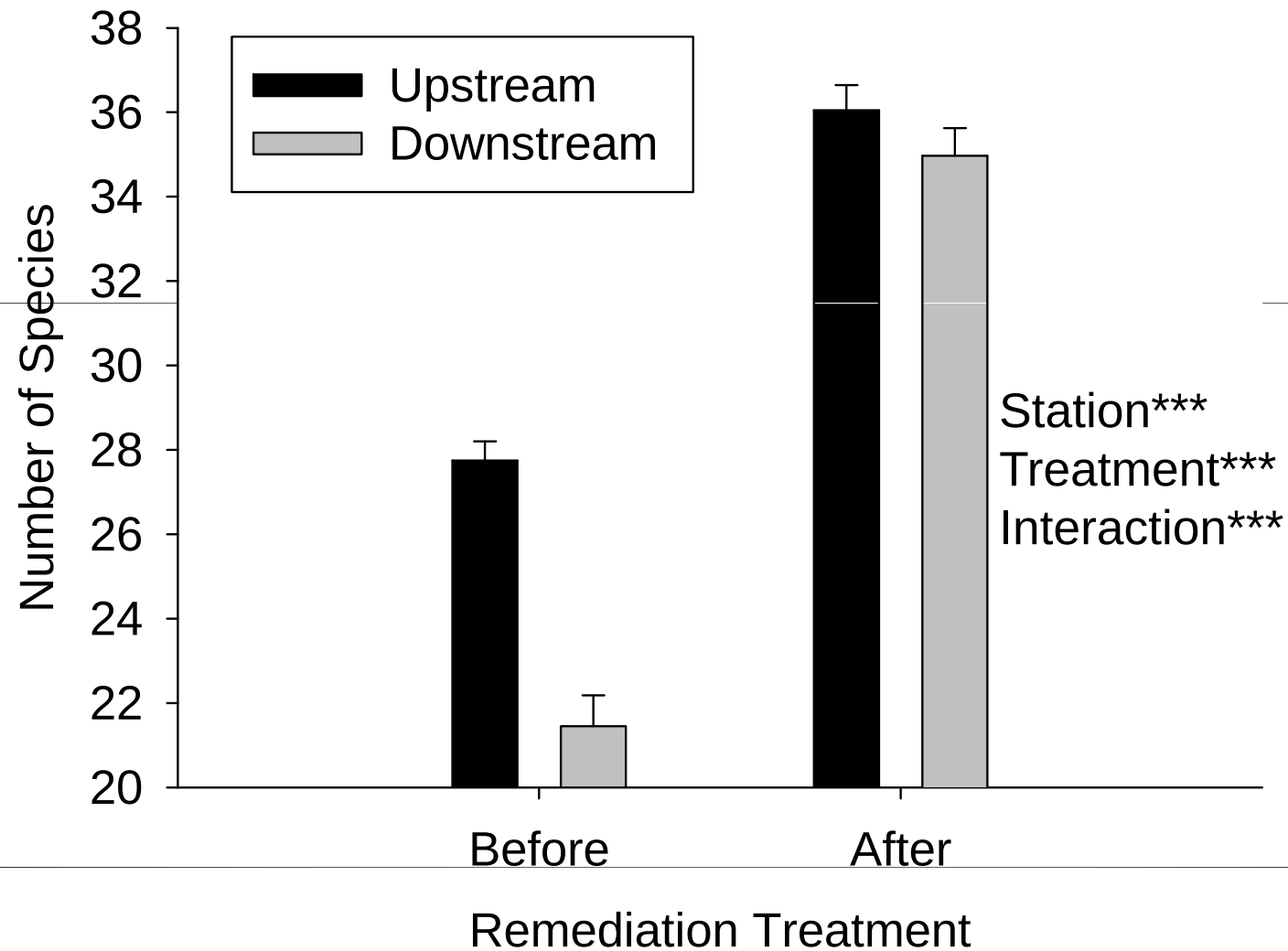


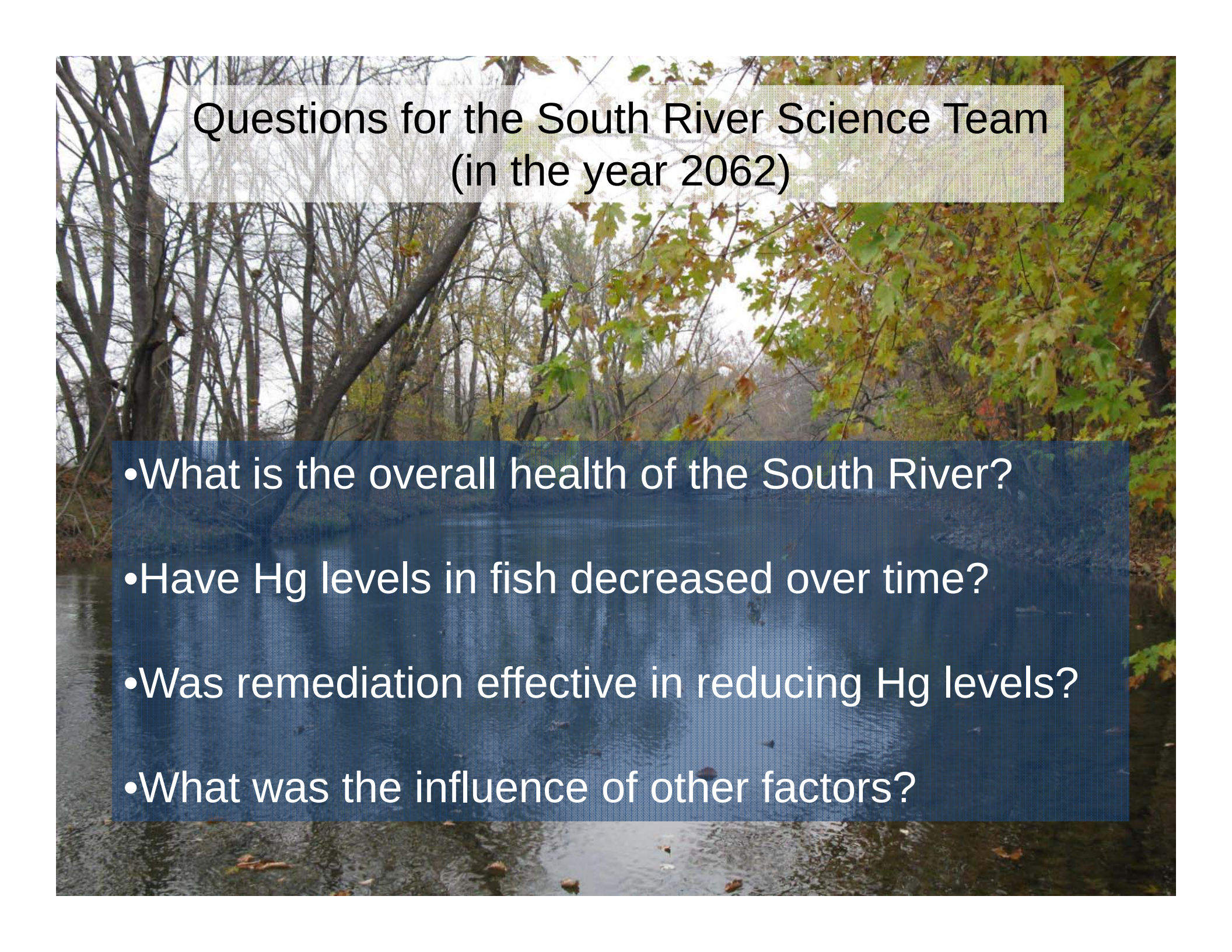
AIC Model Selection:
[Zn], site, year,
discharge

Before-After Control-Impact (BACI) Design



Before-After Control-Impact Design



A photograph of a river flowing through a forest. The water is calm, reflecting the surrounding trees. The trees have autumn foliage in shades of green, yellow, and orange. The sky is overcast and grey. The text is overlaid on the top half of the image.

Questions for the South River Science Team (in the year 2062)

- What is the overall health of the South River?
- Have Hg levels in fish decreased over time?
- Was remediation effective in reducing Hg levels?
- What was the influence of other factors?

In a 1982 settlement between DuPont and the State Water Control Board, a fund was established to support monitoring of water, sediments, and fish tissue in the river system for a projected **100-year period**.

VIRGINIA DEQ

100-YEAR MERCURY MONITORING PLAN

SOUTH RIVER / S. FORK SHENANDOAH RIVER

	1990	92	93	96	97	99	2002	05	07	12	17	22	27	32	37	42	47	52	57	62	67	72	77	82	87	92
FISH	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SEDIMENTS					X				X		X		X		X		X		X		X		X		X	
WATER		X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FLOOD PLAIN									X				X				X				X				X	
CONSULTANT*					X				X		X		X		X		X		X		X		X		X	

* A consultant's report will be prepared every 10 years to address data and trends from water, sediments and fish over the life of the project to date.

At some point during the project a special review of data following a 100-year flood event will be conducted.

QUALITY ASSURANCE PROJECT PLAN

COLLECTION AND ANALYSIS OF FISH TISSUE
FOR MERCURY CONTENT
SOUTH RIVER AND SOUTH FORK
SHENANDOAH RIVER

SPRING 2007

Commonwealth of Virginia
Department of Environmental Quality
Harrisonburg, VA 22801

Highlights of this Document

- Focus on Hg in fish, sediment, water, floodplain
- Details of experimental design and methods
Sites, species (trophic groups) sampled

Predators – smallmouth bass (largemouth bass)

Foragers – redbreast sunfish (rock bass)

Bottom Feeders – white suckers (carp)

() = alternate species

- Comprehensive QA/QC & Data Management Plan

South River, North River, South Fork Shenandoah River, & Shenandoah River

N = 18 stations

Map Key	Station	Location
STRD	STH026.12	Waynesboro City Park above Rife Loth Dam
STDF	STH025.10	Waynesboro City Park north of DuPont footbridge
STSB	STH023.73	Waynesboro near 2 nd Street Bridge
STHP	STH022.75	Downstream of Waynesboro at Hopeman Parkway
STDM	STH020.44	Dooms, VA near Rt. 611 bridge (above dam)
STFC	STH012.71	Crimora, VA at VDF Forestry Center
STHR	STH007.80	Harriston at stream gauge
STGC	STH002.14	Grottoes, VA Town Park near DGIF boat launch
NRMC	NTH004.10	Near Rt. 668 bridge below confluence with Middle River
SFLW	SSF100.10	Lynwood, VA near Rt. 708 bridge
SFSD	SSF078.24	Shenandoah, VA (boat ramp above dam)
SFNA	SSF063.17	Newport Landing south of Alma, VA on Rt. 340
SFWH	SSF054.20	Hamburg, VA near Rt. 211 bridge
SFFO	SSF037.60	Fosters Landing near Rt. 684 bridge
SFBV	SSF020.70	Bentonville Landing near Rt. 613 bridge
SFFR	SSF010.18	DGIF Boat launch – Luray Avenue
SRBF	SHN038.48	Rt. 17/50 bridge
SRCF	SHN022.63	Berryville, near Rt. 7 bridge

Background Information Available

- Comprehensive inventory of Hg in many compartments
- Conceptual model of Hg distribution & transport
→ aquatic and terrestrial pathways
- Excellent understanding of geomorphology & hydrology
- Reasonable understanding of South River ecology
→ population and community studies
- Preliminary results of several remediation projects
- Excellent record of communication

Potential Sources of Uncertainty

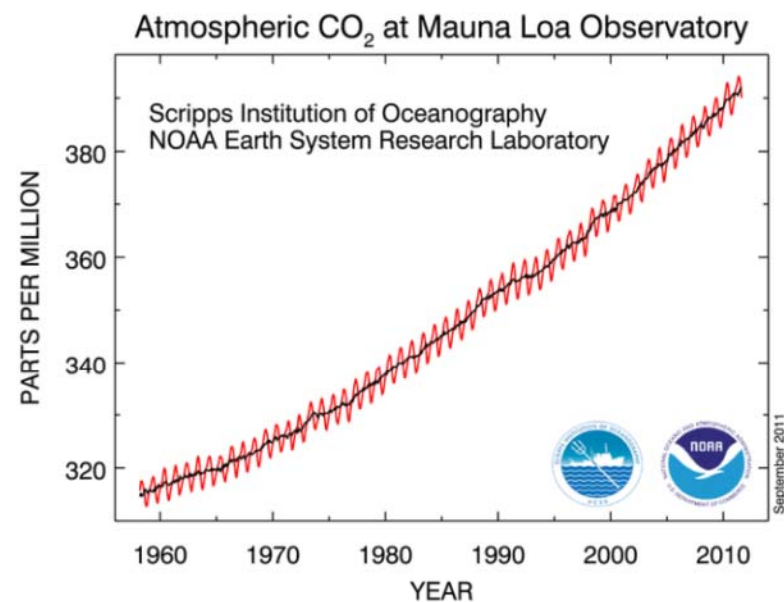
- Longitudinal & lateral extent of contamination
 - Dynamics of contaminant transport
 - Adequacy of source control
-
- Future sedimentation rates & hydrologic conditions
 - Background contaminants and ecological stressors
-
- Changes to site use & impacts on Hg transport
 - Remedy effectiveness & remedy impacts
 - Other factors (e.g., climate change)

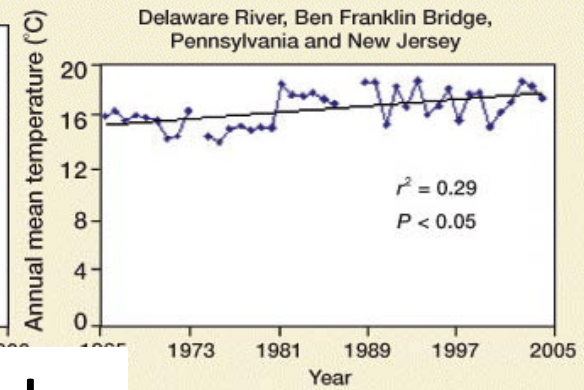
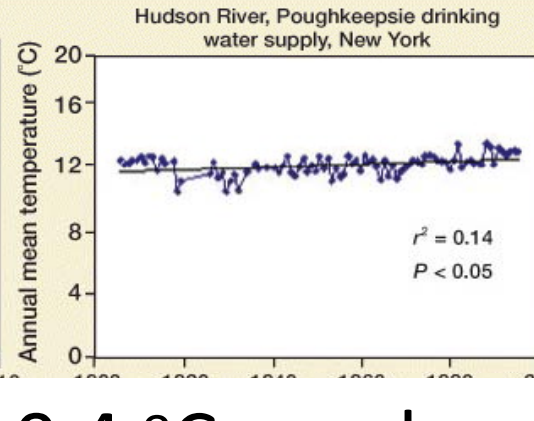
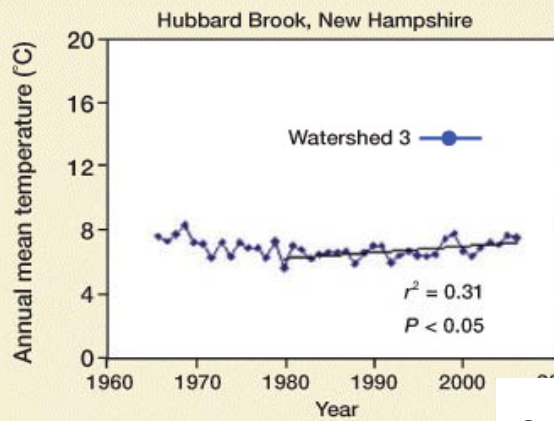
Hydrologic modifications (dam removal)



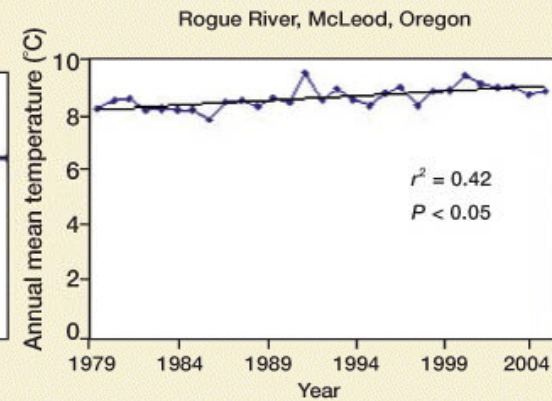
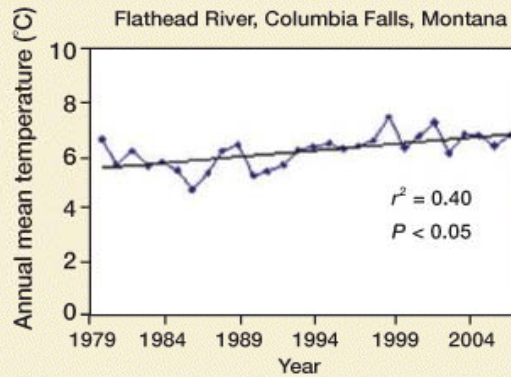
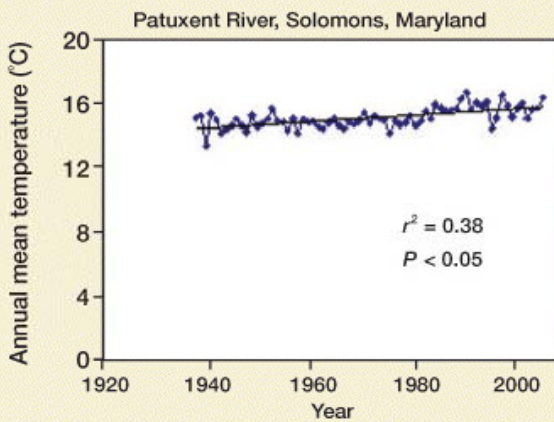
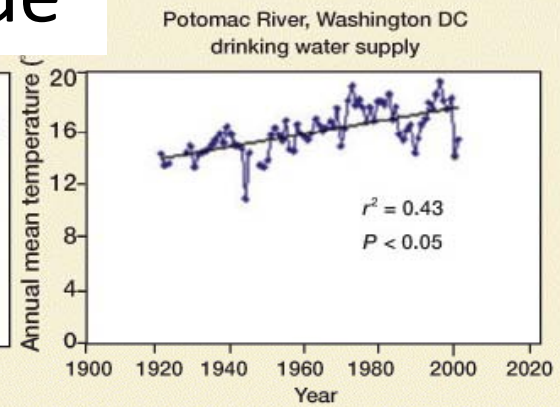
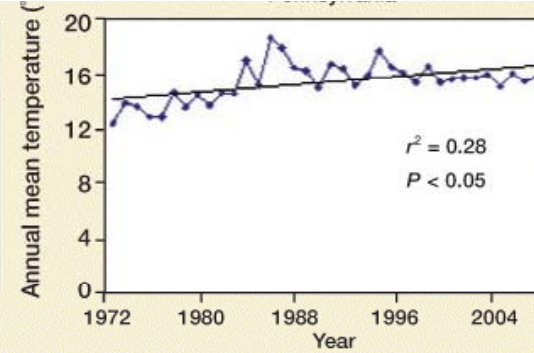
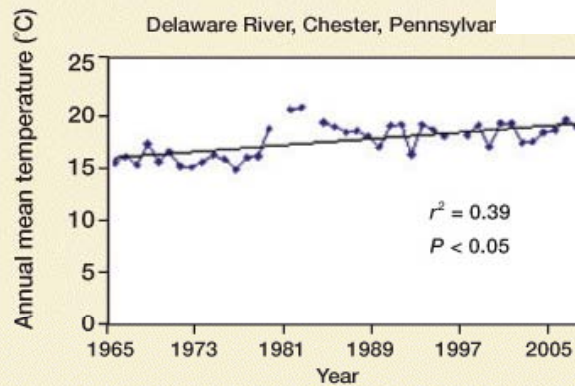
Other Factors

Climate change

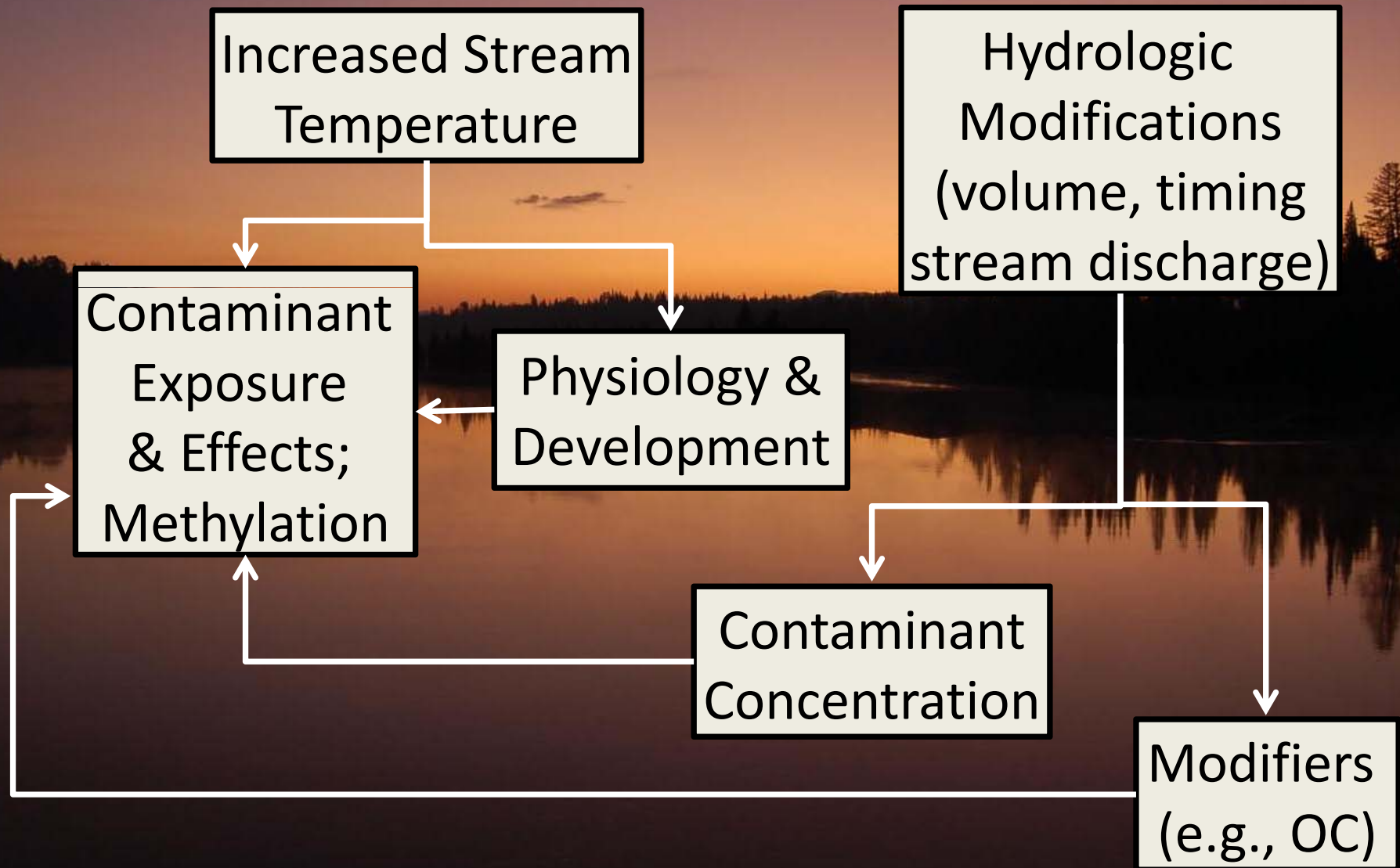




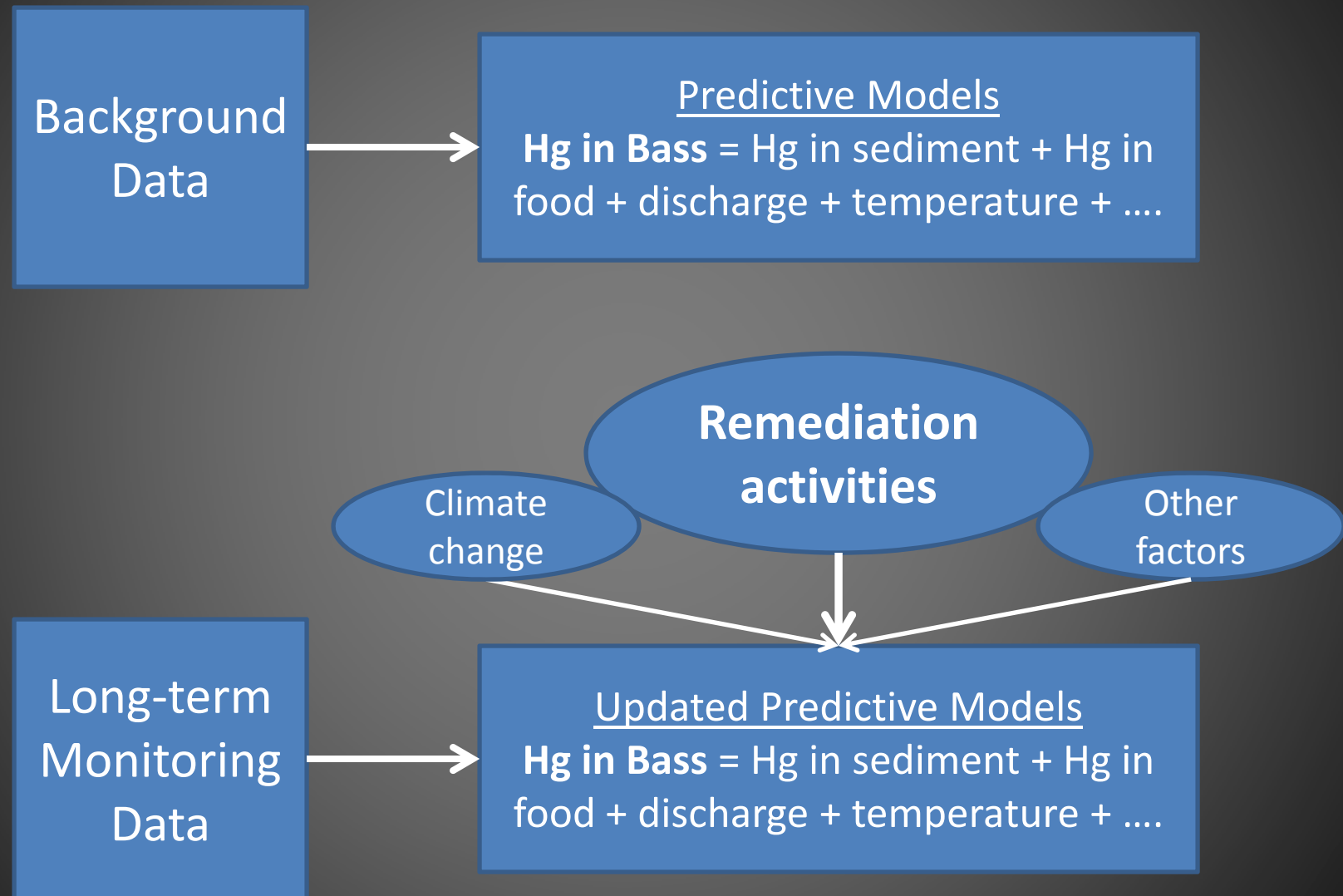
~ 0.4 °C per decade



How Will Climate Change Influence Remediation Effectiveness?



Framework for Long-Term Monitoring of the South River



Other Considerations

- VA DEQ primarily responsible for monitoring
- Will there be sufficient coordination among state, federal and private contractors?
- Will there be an assessment of ecological effects?
need to develop detailed, specific methods
- Adaptive management plan

Homework Assignment for Tomorrow

Come prepared to discuss the following questions related to developing a long-term monitoring plan for the South River watershed

1. What are the long-term monitoring objectives & hypotheses?

2. What should be monitored?

- Hg in water, sediments, fish → models
(total and methyl Hg?)
- Ecological effects?
(surveys, toxicity tests, microcosm expts.)
- Both aquatic and terrestrial resources?

Note: Physical & chemical endpoints are often less expensive, less variable and more easily measured; however, we are generally more interested in biology!

3. What frequency, duration, & spatial extent?

- Should we consider multiple spatiotemporal scales?
specific remediation project → entire watershed
- Any consideration of seasonality?
- How do we know when we are done?
- Are the current sampling sites appropriate to answer the question?

4. Are the current sampling, analytical & statistical methods appropriate and sufficiently detailed?

5. What are the primary sources of uncertainty?