

Linking Sediment Exposure with Effects: Useful Laboratory and Field Assessment Techniques (*déjà vu?*)

Allen Burton

(allen.burton@wright.edu)



Skip Nelson

(nelson.william@epa.gov)



Presentation Outline



- ⌘ Déjà vu?
- ⌘ Review pro's/con's of various methods
- ⌘ Predictability
- ⌘ *Lab to field extrapolations aren't the issue...* Rather lab AND field assessments with proper study design, conceptual model and decision making process
- ⌘ Weight-of-evidence example
- ⌘ Moving forward...

ERA Process Weaknesses: 1995 Pellston Workshop



- ⌘ Establishing stressor causality
- ⌘ Linking/integrating lines-of-evidence
- ⌘ Spatial and temporal variability
- ⌘ Measuring exposure accurately
- ⌘ Extrapolating effects (from tissues, biomarkers, species)
- ⌘ Sampling/testing artifacts
- ⌘ Appropriate reference sites
- ⌘ Linking measurement to assessment endpoints

Strengths & Limitations of Traditional Methods

- ⌘ Criteria: easy, wide use, proven utility
- ⌘ Biota: high certainty, long term measure/integrator, public interest
- ⌘ Bioaccumulation: risk models, long term measure, wide use
- ⌘ Toxicity (lab): wide use, proven utility, integrator
- ⌘ TIE (lab): partitions chemicals, causality
- ⌘ Criteria: single chemical, causality, extrapolation, exposure reality
- ⌘ Biota: causality, indirect effects, variability, natural stressors
- ⌘ Bioaccumulation: thresholds, metabolism, acclimation
- ⌘ Toxicity (lab): causality, extrapolation, chronic costs, natural stressors
- ⌘ TIE (lab): artifacts, insensitive

Strengths & Limitations of Non-Traditional Assessment Methods

- ⌘ Habitat: essential to life, dominant stressor
- ⌘ GW/SW Flow: documents exposure, compartmentalize stress
- ⌘ *In situ* Toxicity and Uptake: improved exposure, compartmentalize stress, minimize artifacts
- ⌘ *In situ* TIE: improved exposure, minimize artifacts, sensitive
- ⌘ Habitat: receptor specific, quantification
- ⌘ GW/SW Flow: logistics
- ⌘ *In situ* Toxicity and Uptake: logistics, reference site, acclimation, proper deployment
- ⌘ *In situ* TIE: logistics, proper deployment, screening only

Predictability of Various Lines-of-Evidence

⌘ SQGs: benthos 70%; lab tox 60%; *in situ* sed tox 58%; *in situ* water tox 48%

⌘ PCB SQGs (CB-PEC): benthos 67%; lab tox 46%; *in situ* sed tox 60%; *in situ* water tox 50%

⌘ Metal SQGs (CB-TEC): benthos 69%; lab tox 57%; *in situ* sed tox 54%; *in situ* water tox 51%

⌘ Metal SQGs (AVS): benthos 67%; lab tox 51%; *in situ* sed tox 57%; *in situ* water tox 45%

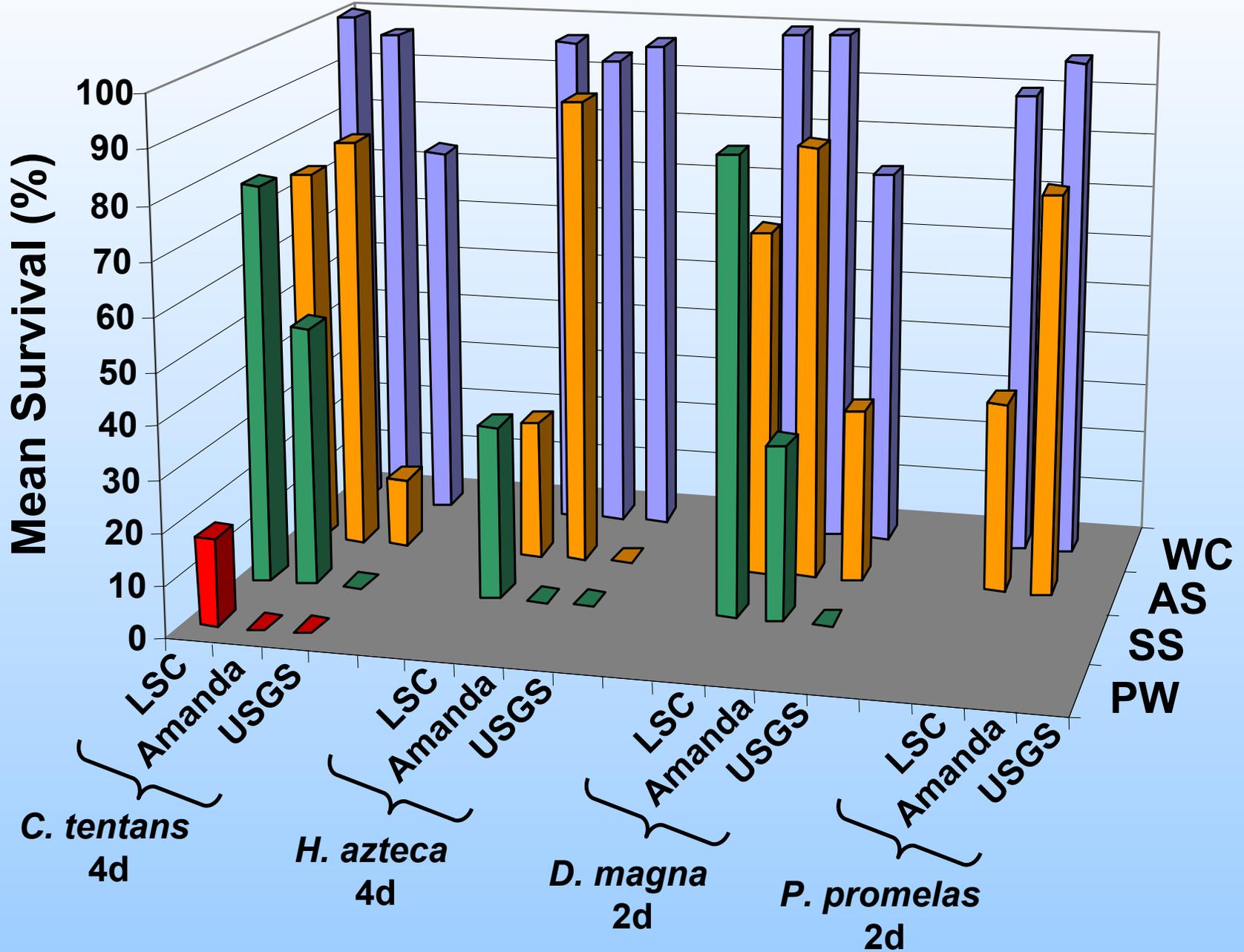
⌘ PAH SQGs (CB-PEC): benthos 78%; lab tox 84%; *in situ* sed tox 62%; *in situ* water tox 46%

⌘ Lab sed tox: benthos 51%

⌘ *In situ* tox (W+S): benthos 55%

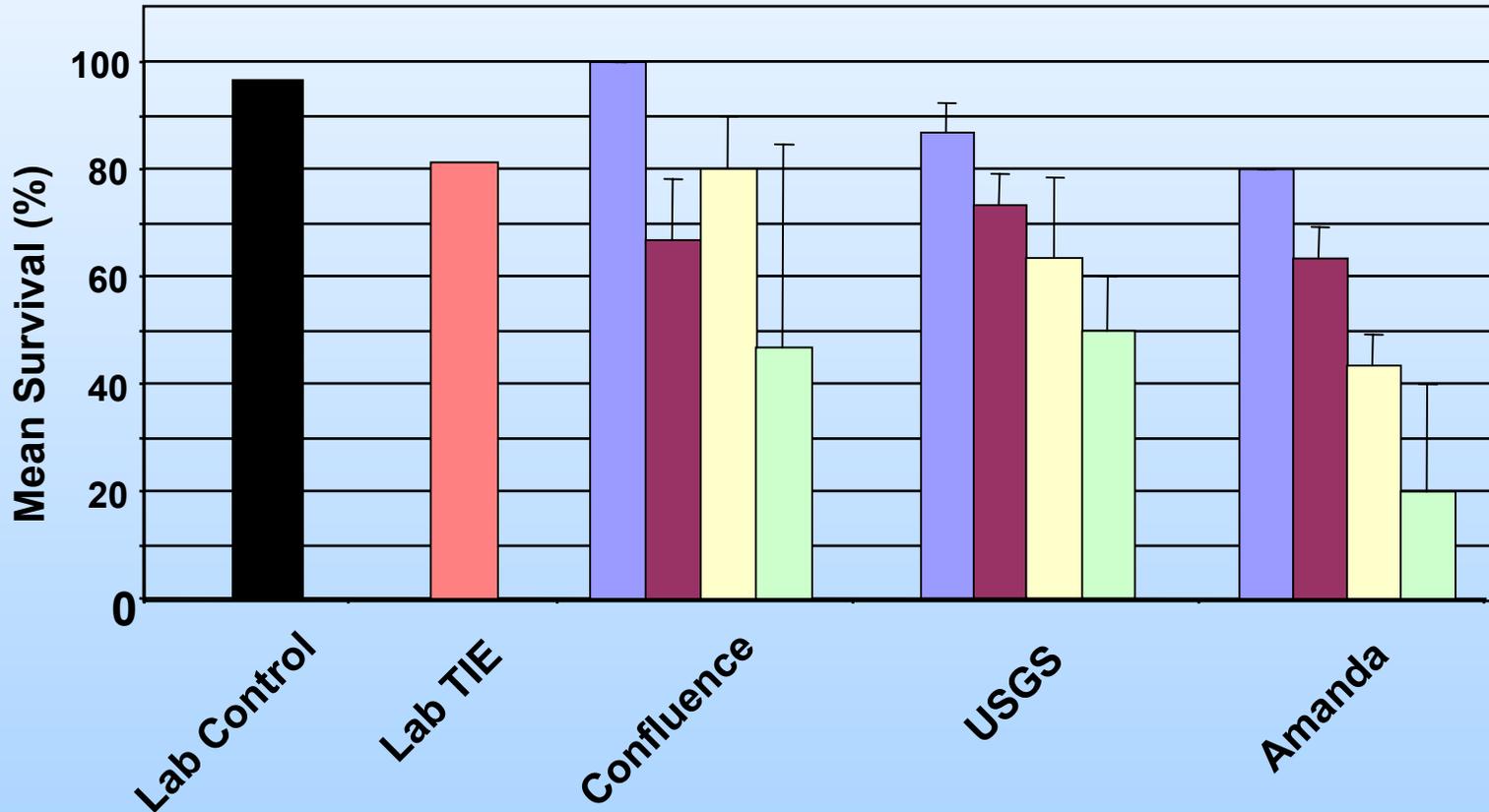
⌘ *In situ* sed tox: benthos 59%

In Situ Toxicity Test



In Situ TIE

- Ambersorb
- Zeolite
- Chelex
- Pore



D. magna survival (\pm SD) following an *in situ* TIE exposure

Matching Exposure with Effects: Issues



- ⌘ Benthos exposed to overlying water (low and high flow), pore water, groundwater upwellings, sediments, colloids and suspended solids, food
- ⌘ Each exposure compartment has unique spatial/temporal dynamics
- ⌘ Must assess all compartments to establish role of sediments
- ⌘ Must assess natural stressors and natural dynamics to determine hazard/risk.

Conclusions (1998-2001 WOE Studies)



- ⌘ No single LOE reliably predicts ecosystem impairment; typically 40-70% accurate. Each LOE provides unique, not duplicative information.
- ⌘ Multiple species/compartments must be evaluated across space and time.
- ⌘ Biological responses (e.g., *in situ* caged species and benthic indices) most reliable LOE for assessing short and long-term impairment.

A Second Perspective: Background

- ⌘ Confused as to what I should present
 - ⊞ My current sediment-related activities involve monitoring, not SERA
- ⌘ Co-worker pointed me to the 1995 Pellston Workshop Proceedings, *"Ecological Risk Assessment of Contaminated Sediments"*
- ⌘ Suggested "best course of action":
 - ⊞ Empirical, site-specific relationships between sediment exposures and effects endpoints
 - ⊞ "Weight-of-evidence" (WOE) approach

Example Addressing Exposure & Effects Issues Using WOE Approach

⌘ New Bedford Harbor Long-Term Monitoring Program (NBH-LTM)

☒ Multiple “Lines Of Evidence” (LOE):

☒ Exposure/Effects

- PCB Concentration & benthic community

☒ Lab/Field Relationships

- Sediment toxicity & benthic communities

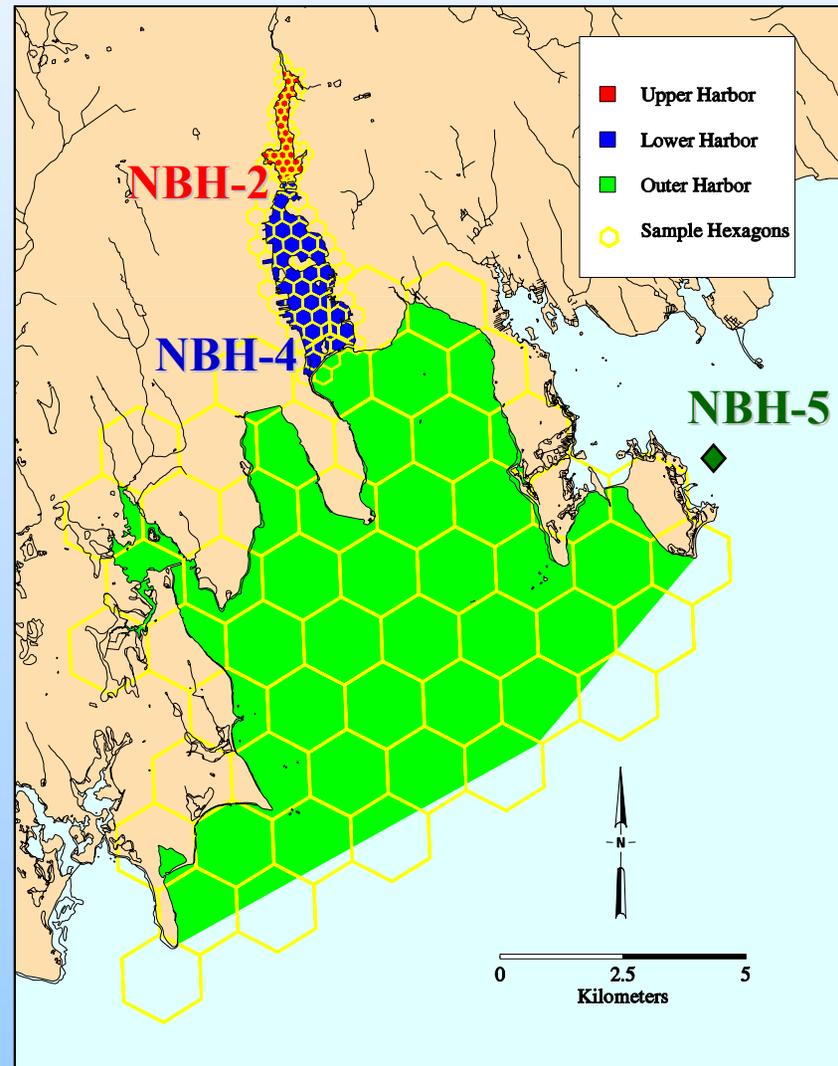
☒ Multiple Compartments

☒ Benthic & water column

☒ Spatial/temporal Considerations

New Bedford Harbor Long-Term Monitoring Program

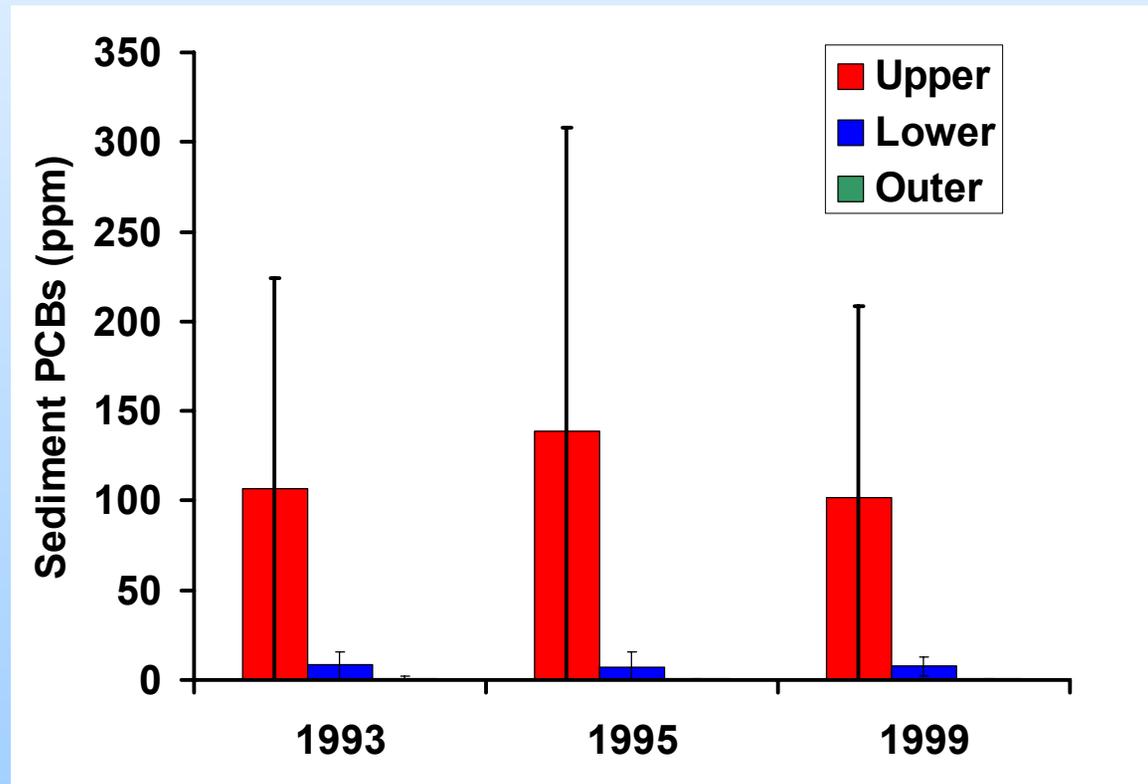
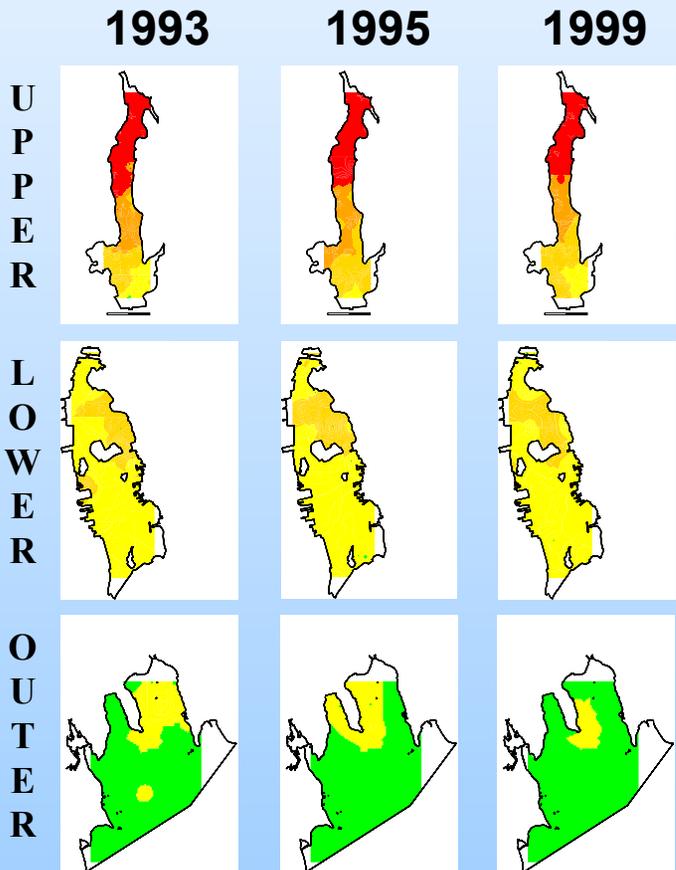
- ⌘ Exposure/Effects Data
 - ⌘ PCBs, metals, sediment toxicity, benthic community, bioaccumulation, etc.
- ⌘ Spatial Considerations:
 - ⌘ Probabilistic design
 - ⌘ 72 stations
- ⌘ Temporal Considerations:
 - ⌘ Three collections to date: 1993, 1995, 1999



Individual LOE Can: Document Exposure Spatially & Temporally

GIS Analysis (Qualitative)

Statistical Analysis (Quantitative)

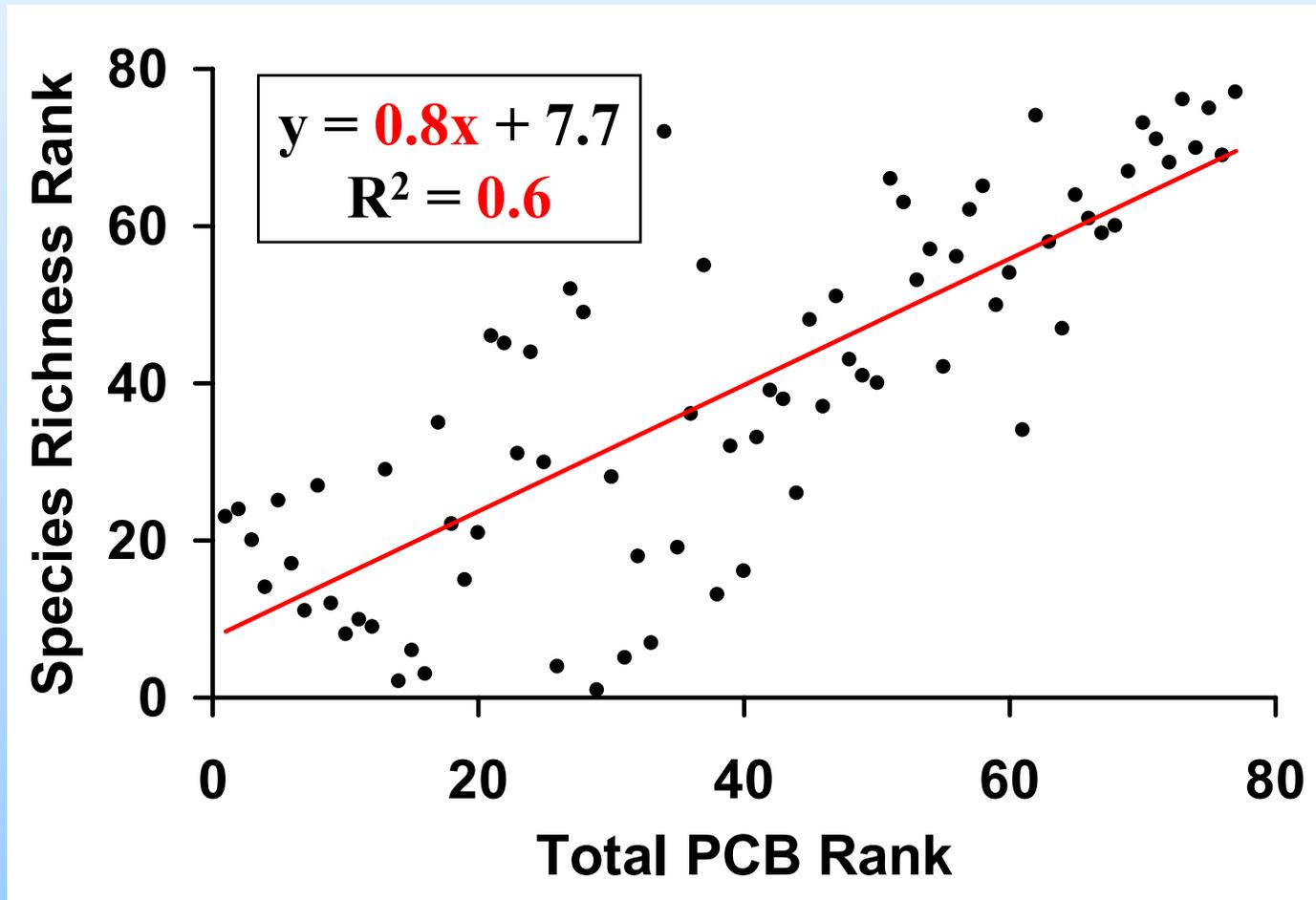


Total PCBs (ppm)

■ > 100	■ 51 - 100	■ 11 - 50
■ 1 - 10	■ < 1	

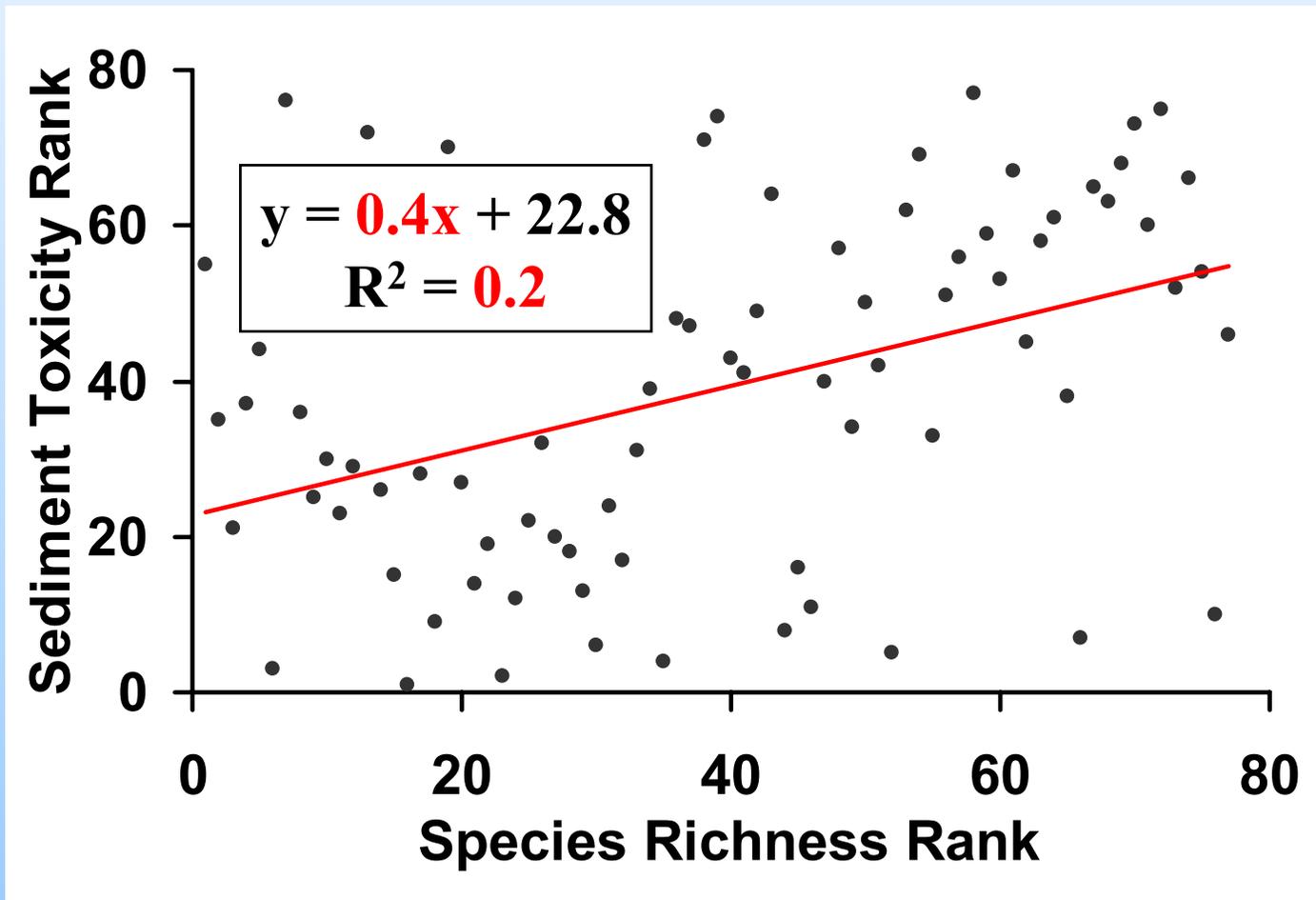
Multiple LOE Can: Correlate Field Exposure & Effects

1993



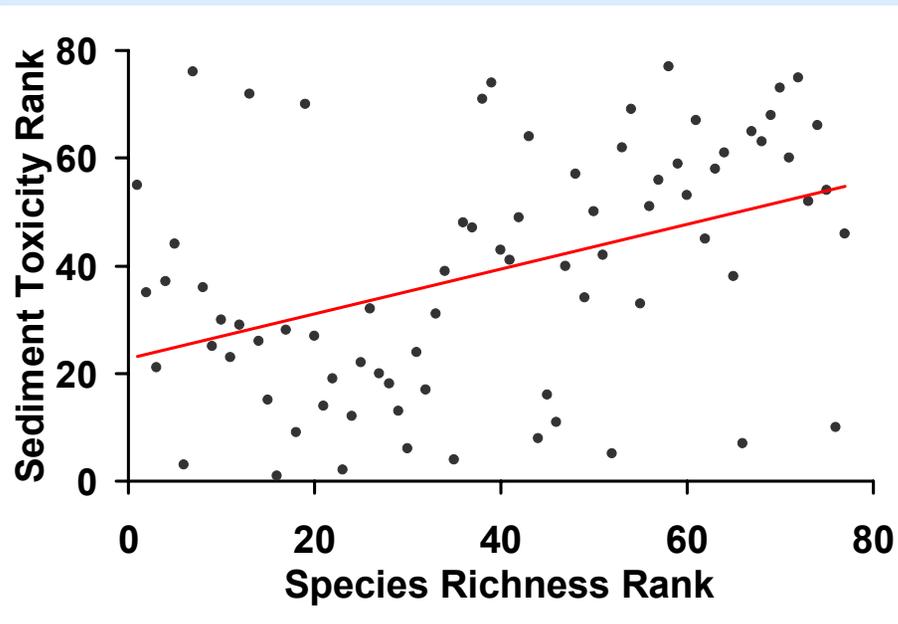
Multiple LOE Can: Correlate Lab & Field Effects

1993



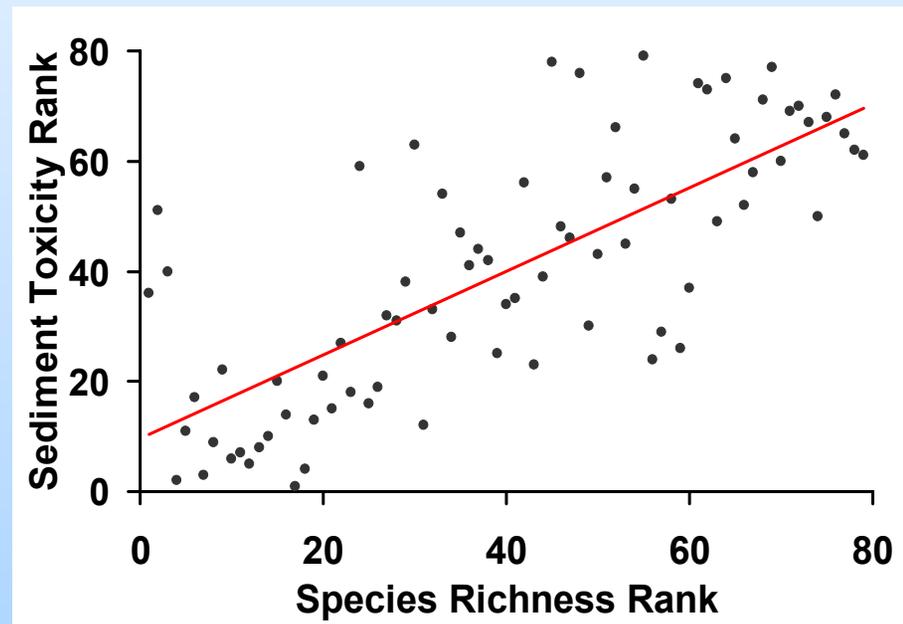
Multiple LOE Can: Change Temporally

1993



$$y = 0.4x + 22.8$$
$$R^2 = 0.2$$

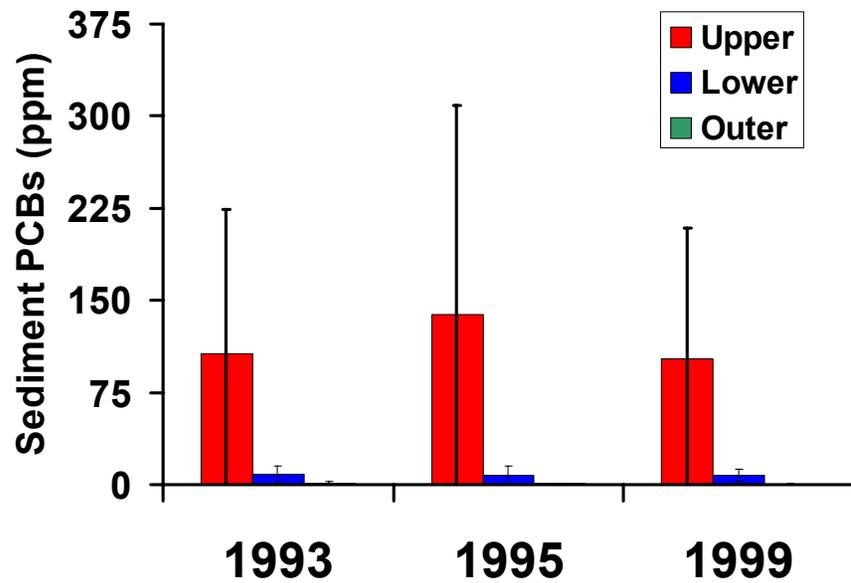
1999



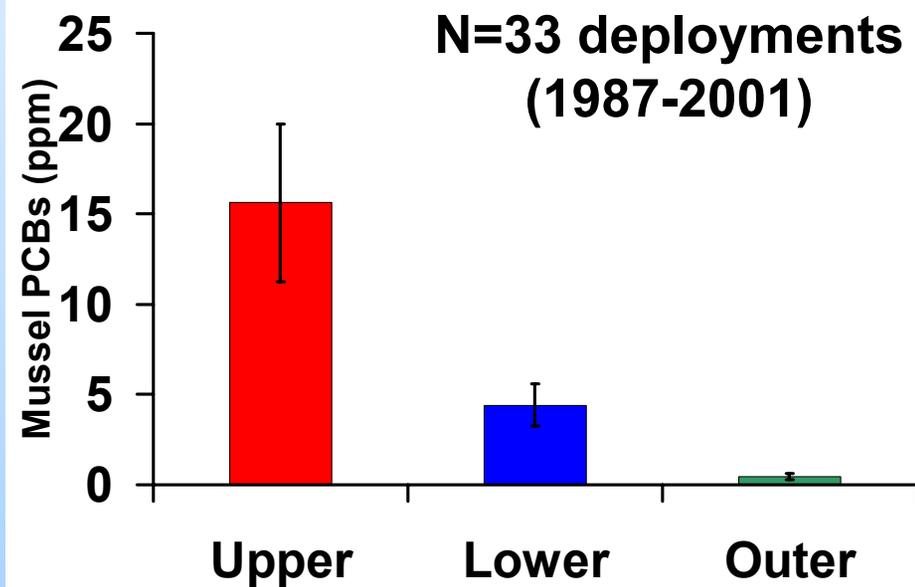
$$y = 0.8x + 9.6$$
$$R^2 = 0.6$$

Individual LOE Can: Include Multiple Compartments (Sediment & Water Column Exposures)

Sediment PCB Concentrations



Mussel PCB Concentrations



WOE Approach: Advantages & Disadvantages

⌘ Advantages:

- ☒ Document exposures and effects spatially & temporally, using qualitative & quantitative analyses
- ☒ Evaluate exposure & effects relationships in multiple compartments in both the lab & field

⌘ Disadvantages:

- ☒ Cannot provide predictive capability (i.e., correlation is not causality)
- ☒ Cannot predict clean-up levels (i.e., is 10 ppm PCBs really more protective than 50 ppm)
- ☒ While individual LOE are quantitative; WOE approach may be subject to using only qualitative BPJ

Discussion Topics: Linking Sediment Exposures & Effects

- ☒ More site-specific empirical data (*e.g.*, the NBH-LTM approach)?
 - ☒ Is WOE approach more relevant to Risk Management (i.e., exposure/effects relationships) than Risk Assessment (i.e., predictive capability)?
- ☒ Establish more mechanistic link between exposures and effects across sites based on specific stressors?
- ☒ Do we need a “Bigger Picture” plan among EcoRisk groups, both Fed and non-Fed?
 - ☒ No plan to show how “pieces” eventually fit together (i.e., integration and synthesis)
 - ☒ Develop interactively between EcoRisk assessors-scientists-managers

Tier 1: Stress Demonstration

Site Reconnaissance

Sample Design Issues

- Bioaccumulation - *tissue design*
- PAHs - *phototox testing*
- GW/SW interactions - *piezometer design*

Exposure

reference sites vs. stressor gradient

Compartment

- Water column
- Interface (sed/water)
- Surficial sediment
- Pore water

Event

- Low flow
- High flow
- Seasonal
- Diel

Period

- 1- 30 d

Physicochemical Profiles

Effects

Species

- *H. azteca*
- *D. magna*
- *C. dubia*
- *P. promelas*
- *C. tentans*
- *L. variegatus*
- Other

Measurement Endpoints

- Survival
- Growth
- Reproduction
- Tissue

Weight of Evidence

- Lab tox testing
- Chemistry + SQGs
- Indigenous biota structure/function indices, genetic profiling, fish DELTs, hyporheous)
- Habitat (QHEI)
- Food web modeling
- Retrospective studies

Tier 2: Stressor Class Identification

- Physical stressors (*flow, temperature, suspended solids*)
- Chemical stressor (*PAHs, nonpolars, metals, ammonia*) classes
- *In Situ* testing - *In situ Toxicity Identification Evaluations (TIE)*
- Laboratory testing - *Toxicity Identification Evaluation Phase 1*

Tier 3: Stressor & Source Confirmation

Weight-of-Evidence Framework

(Madrid Wkshp 2001)

