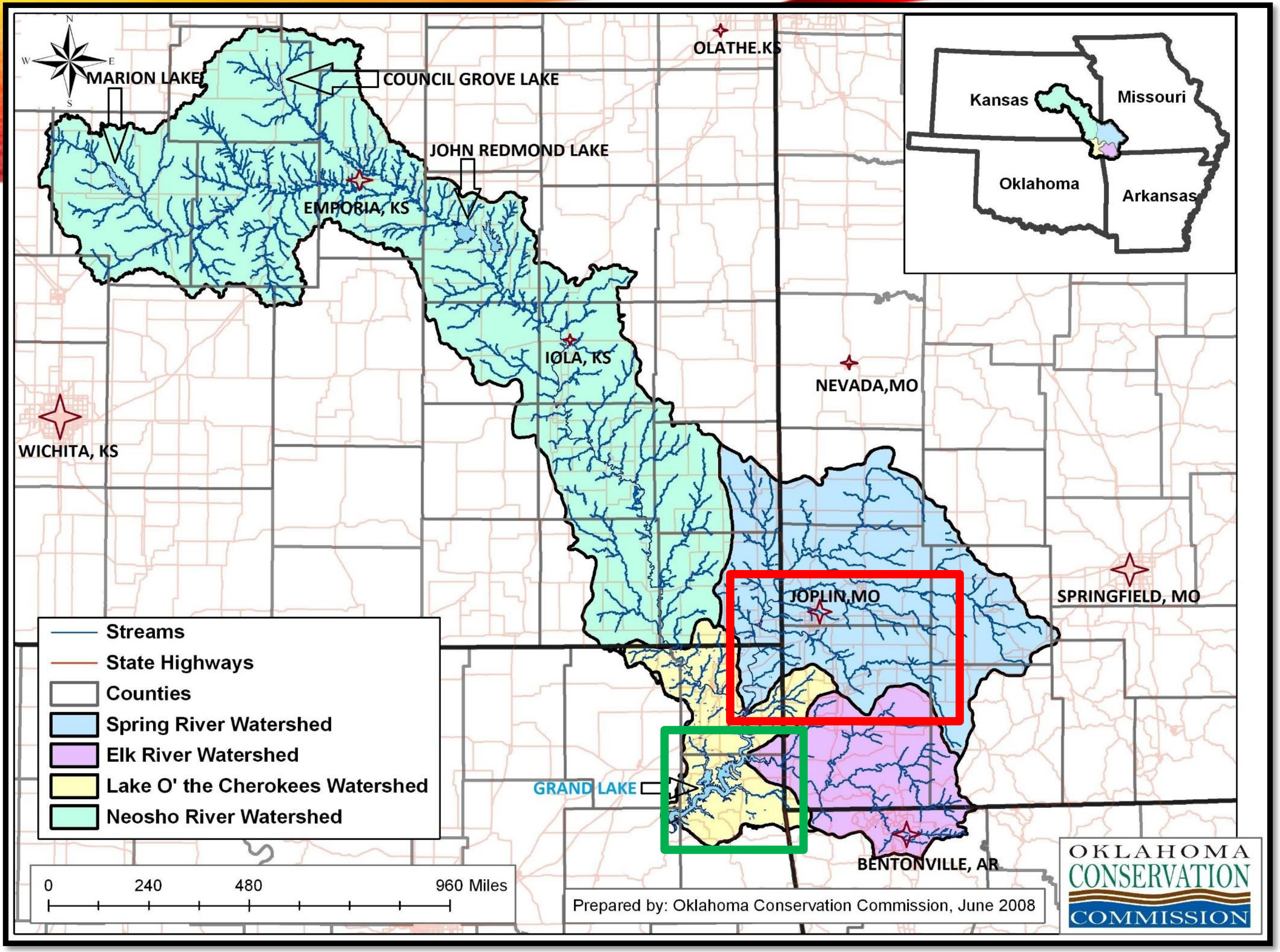
Distribution and Bioavailability of Trace Metals in Shallow Sediments from Grand Lake, OK

Shane Morrison; Stephen Nikolai; Darrell Townsend; Jason Belden



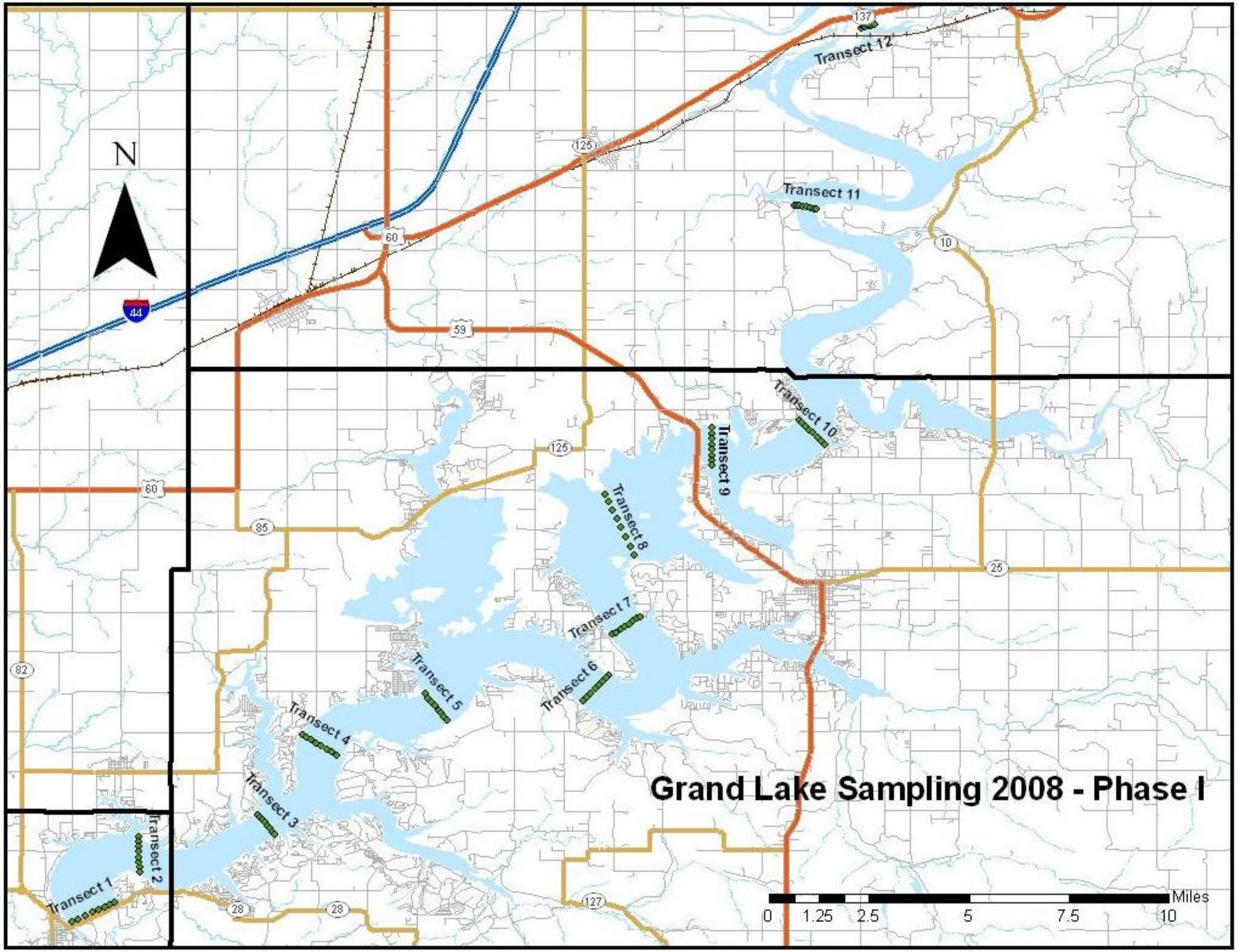
Background

Grand Lake Watershed

- Drainage area
    - 26,000 km^2

Problem Identification

- Tri-State Mining District (TSMD)
    - 6,500 km^2
    - Historic mining for lead and zinc
- Tar Creek Superfund Site



Background

Previous Investigations

Main Lake Body

- McCormick & Burks (1987)
- Burks & Wilhm (1995)
- Dudding (2008)
- Ingersoll et al. (2009)

Watershed

- Juracek et al. (2008)
- MacDonald et al. (2009)

Key Points

- Sparse transects
    - Mostly deep water sites
- Elevated sediment concentrations
- No evidence of toxicity
- Development of hazard categories

Threshold Terminology

Sediment Quality Guidelines (SQGs)

- **TEC** – Threshold Effect Concentration. General concentration threshold below which represent a limited hazard
- **PEC** – Probable Effect Concentration. General concentration threshold above which indicate a probable hazard
- **TEC-PEC** – Intermediate concentration range of undetermined hazard
- **TSMD-Specific PEC** – Probable hazard threshold specific to the TSMD watershed
  - Reflection of unique water chemistries of streams within the watershed

Trace Metal	General Thresholds (mg/kg)		TSMD-Specific (mg/kg)
	TEC	PEC	PEC
Cadmium	0.99	4.98	11.1
Lead	35.8	128	150
Zinc	121	459	2083

MacDonald et al. (2000); MacDonald et al. (2009)

Project Objectives

Objective 1:

- Develop a comprehensive distribution map of shallow sediment trace metal concentrations (specifically cadmium, lead, and zinc) for the upper reaches of Grand Lake.

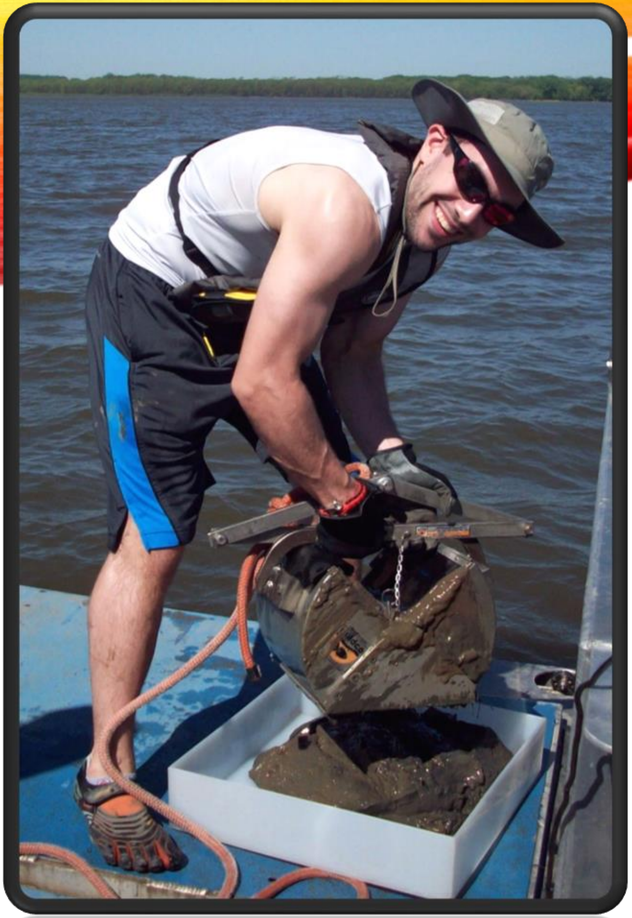
Objective 2:

- Quantify availability of sediment-bound trace metals under natural and disturbed conditions using growth and survival for two aquatic invertebrate species.

Sub-objective:

  - Determine if TSMD – Specific SQGs are appropriate for management purposes on Grand Lake.

Methods – Sediment Sampling



Target Shallow Areas
(≤ 6 m at 741’ elevation)

Randomly Select
Sampling Sites (n=90)

Ponar Dredge

Unsuccessful
(rock/gravel substrate)

Haphazardly Select
Nearby Site
(admit defeat)

113 sites visited
67 successes

Successful
(sand/silt/clay substrate)

Homogenize and Analyze
(Cd, Pb, and Zn)

Methods – Organism Exposures

Resample 12 Sites
(Elk, Grand, & Spring R.)

Homogenize and Setup
Experimental Units
(n=6 per species)

Hyalella azteca
(n=10 per unit)

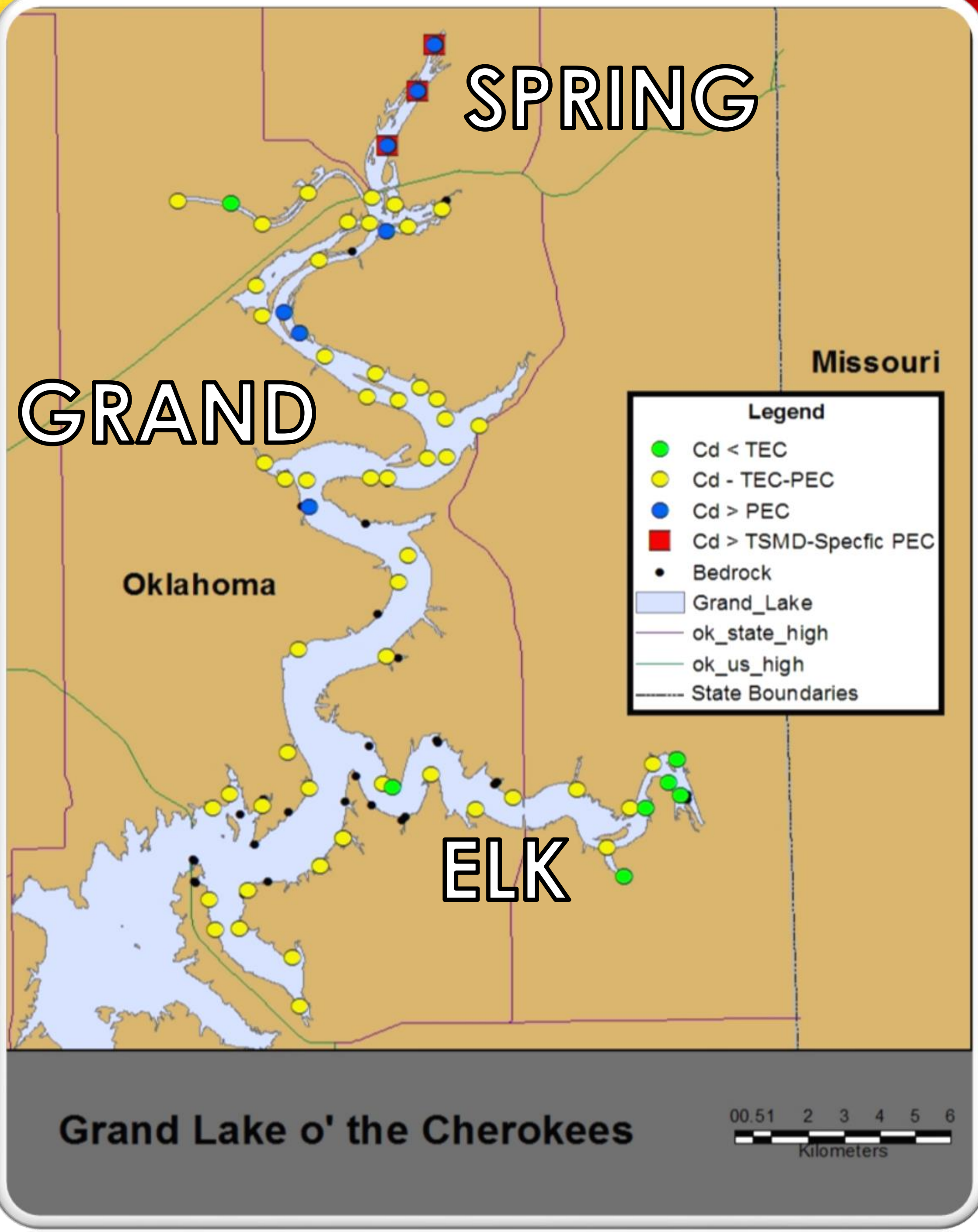
250-500 μm
size class

Assess mortality and growth (dry weight)

Helisoma trivolvis
(n=10 per unit)

5-9 mm
size class

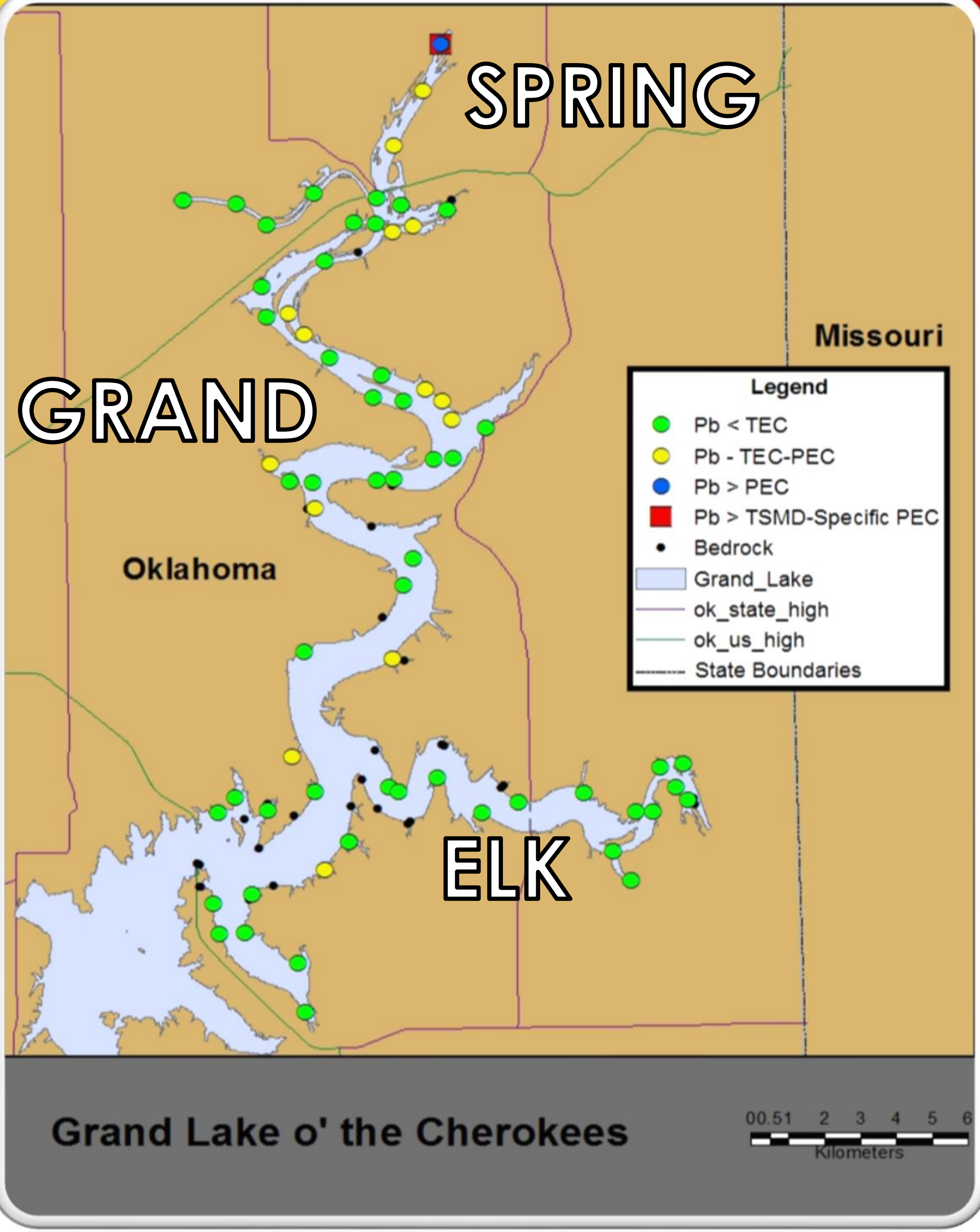
Assess mortality and growth (wet weight)



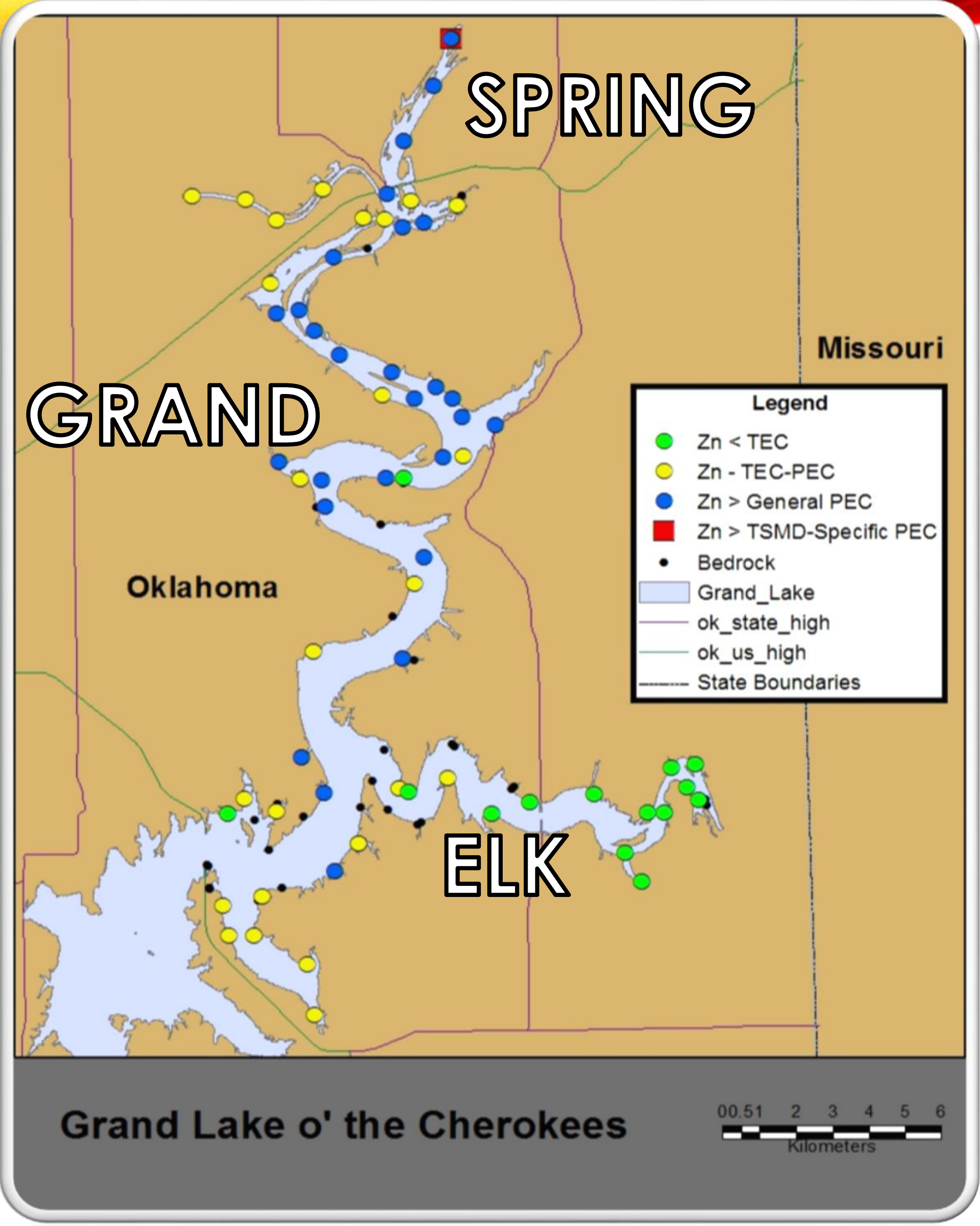
Results – Cadmium (Cd)

Sediment Quality Threshold	Detection Frequency (%)
< TEC	10.45
TEC – PEC	79.1
> PEC	10.45
> TSMD – PEC	4.5

Results – Lead (Pb)



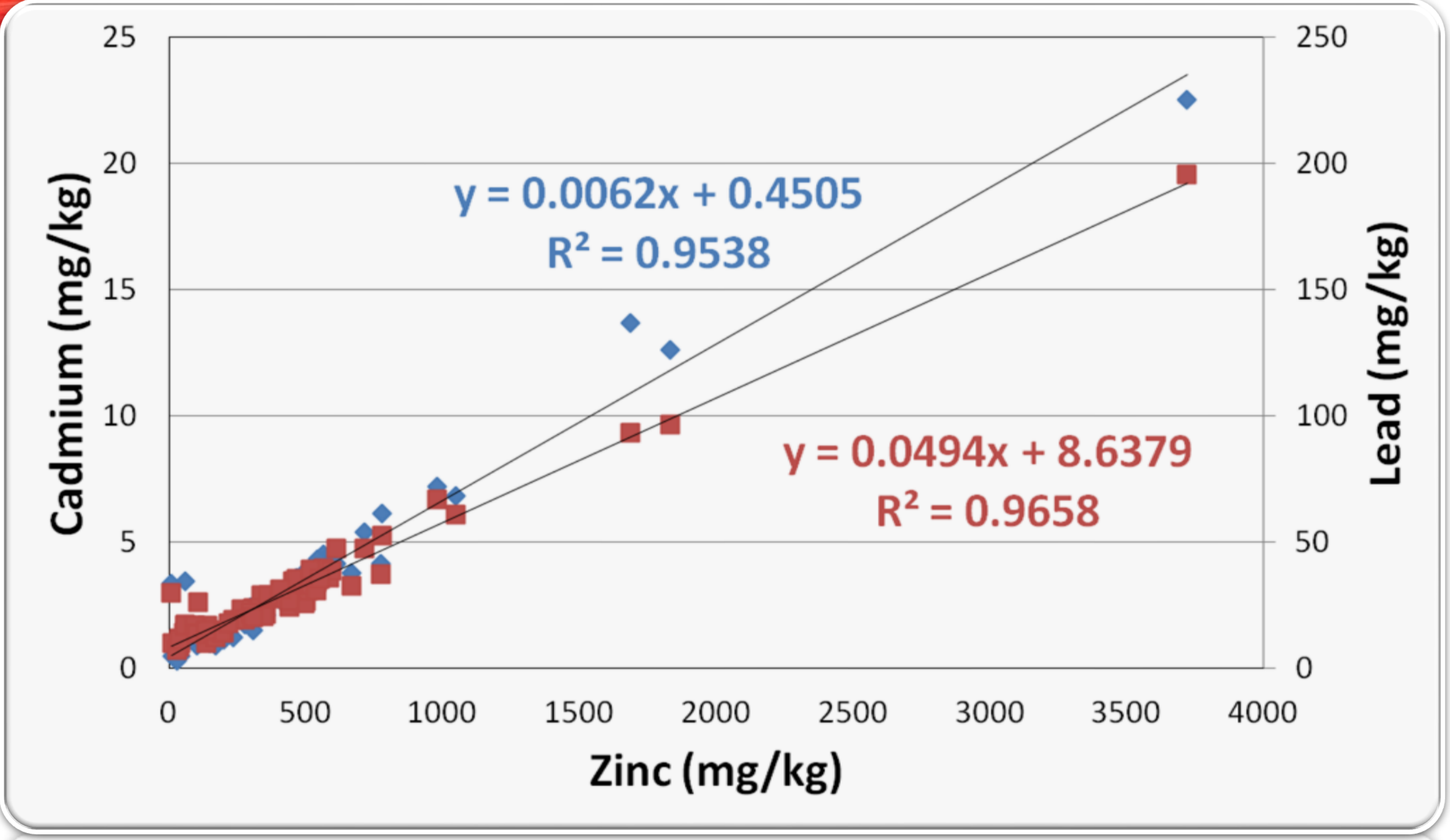
Sediment Quality Threshold	Detection Frequency (%)
< TEC	77.6
TEC – PEC	20.9
> PEC	1.5
> TSMD – PEC	1.5



Results – Zinc (Zn)

Sediment Quality Threshold	Detection Frequency (%)
< TEC	20.9
TEC – PEC	38.8
> PEC	40.3
> TSMD – PEC	1.5

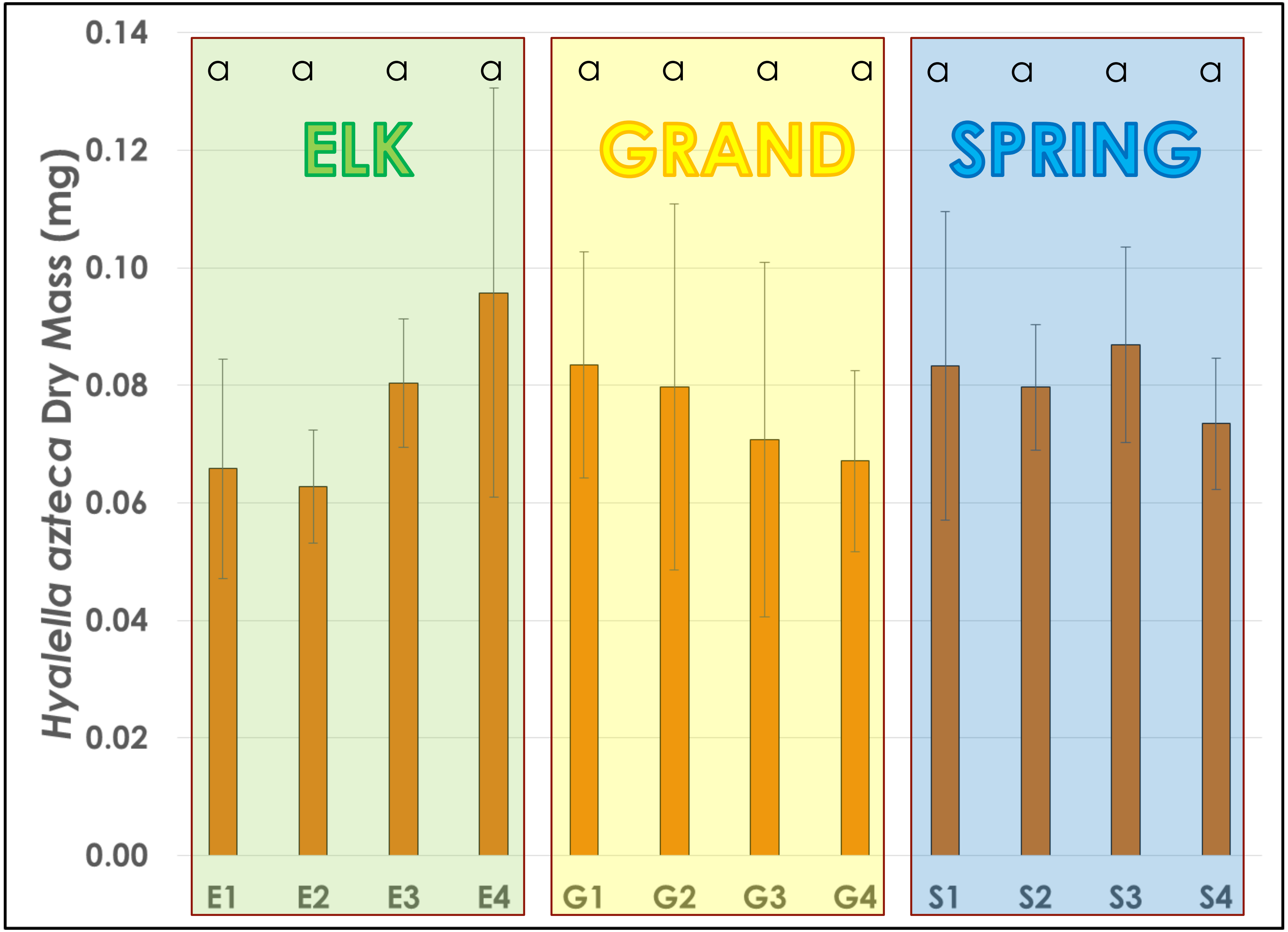
Results – Correlations by Site



Results – Lake Conditions

Survival Assessment

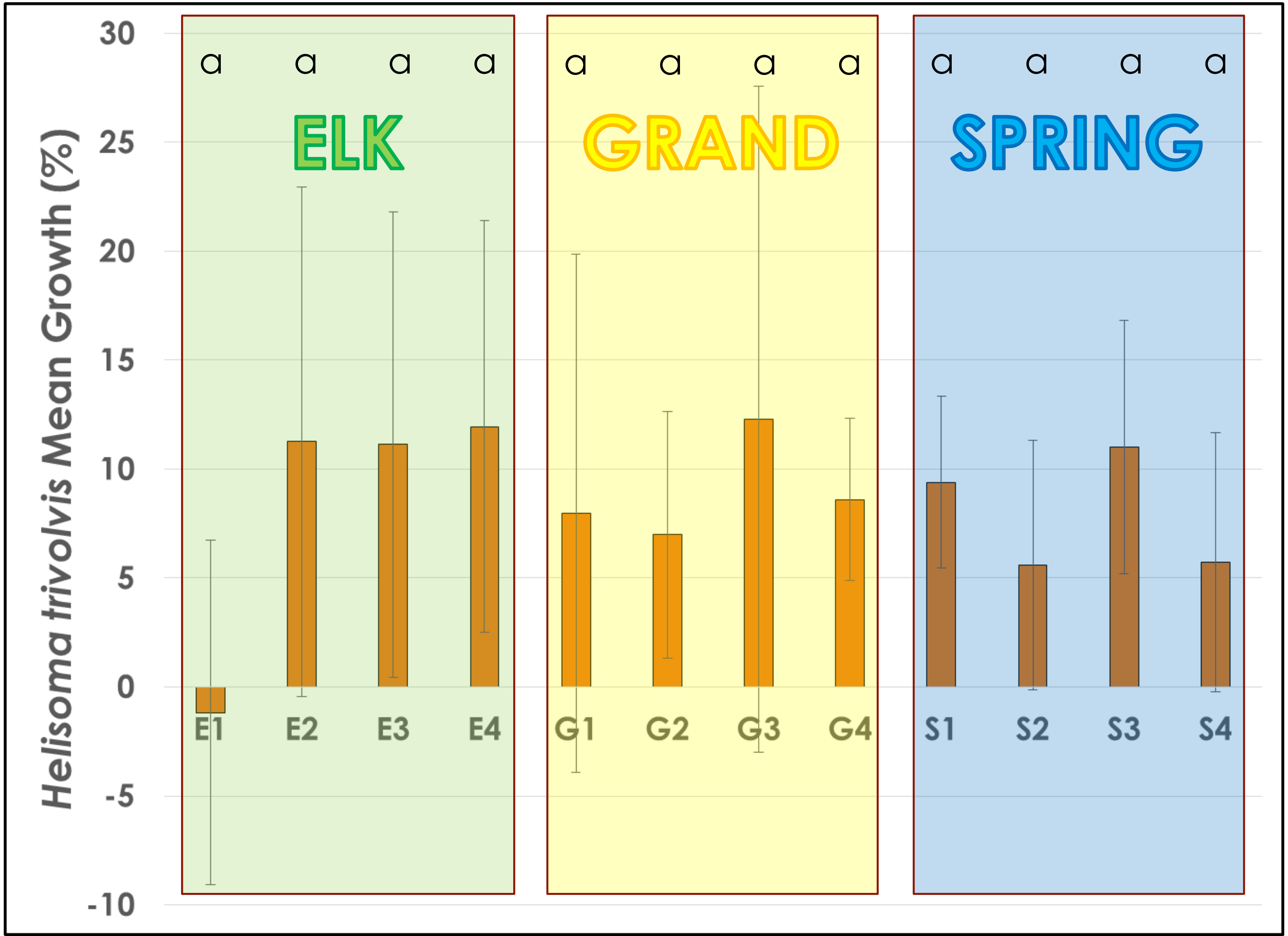
- No significant differences (a = 0.05)
- Most Survivors:
  - 100% (n = 33)
- Fewest Survivors:
  - 60% (n = 3)
- Average Survival:
  - 90%



Results – Lake Conditions

Survival Assessment

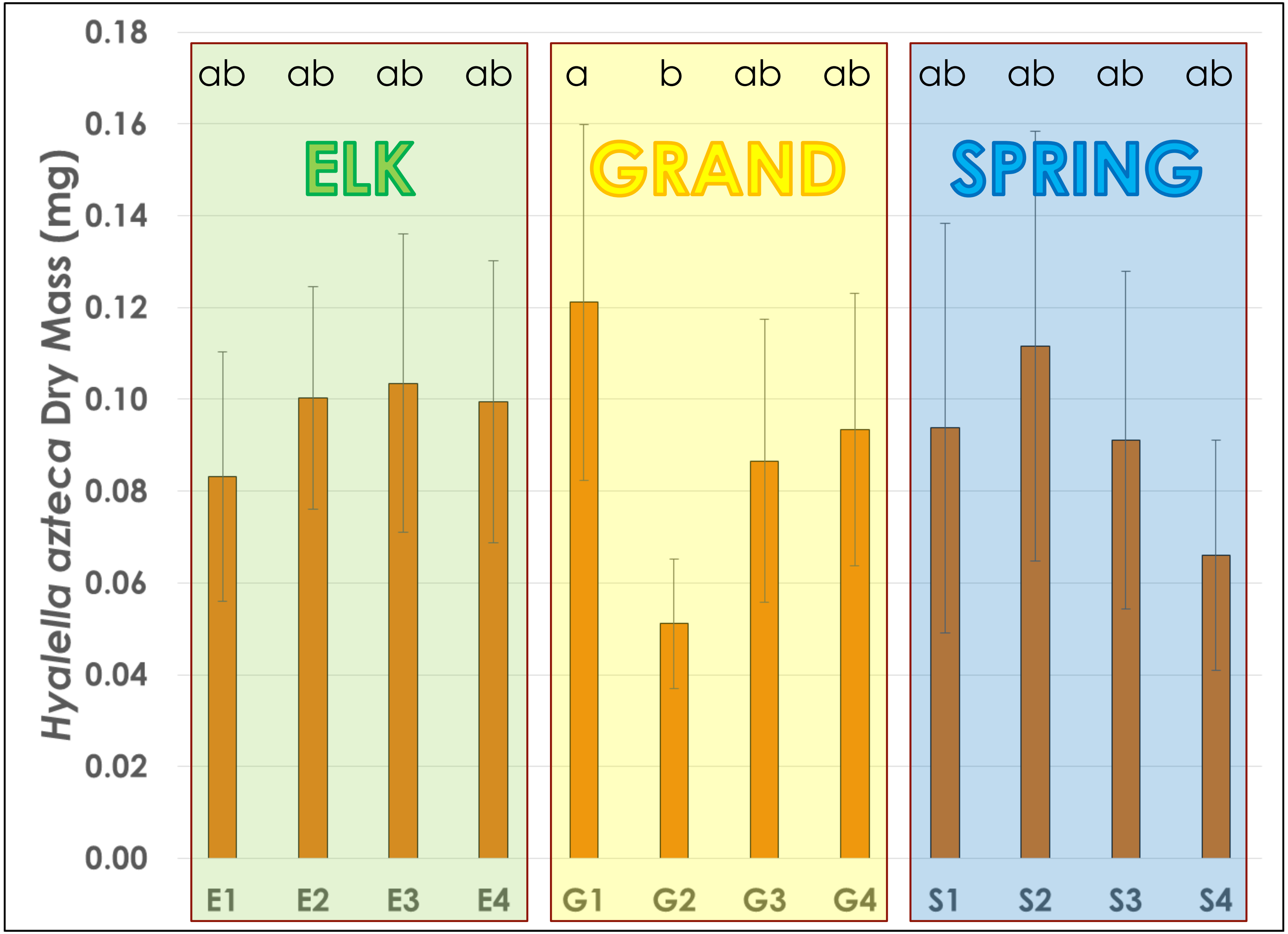
- No significant differences (a = 0.05)
- Most Survivors:
  - 100% (n = 63)
- Fewest Survivors:
  - 80% (n = 1)
- Average Survival:
  - 98%



Results – Disturbed Conditions

Survival Assessment

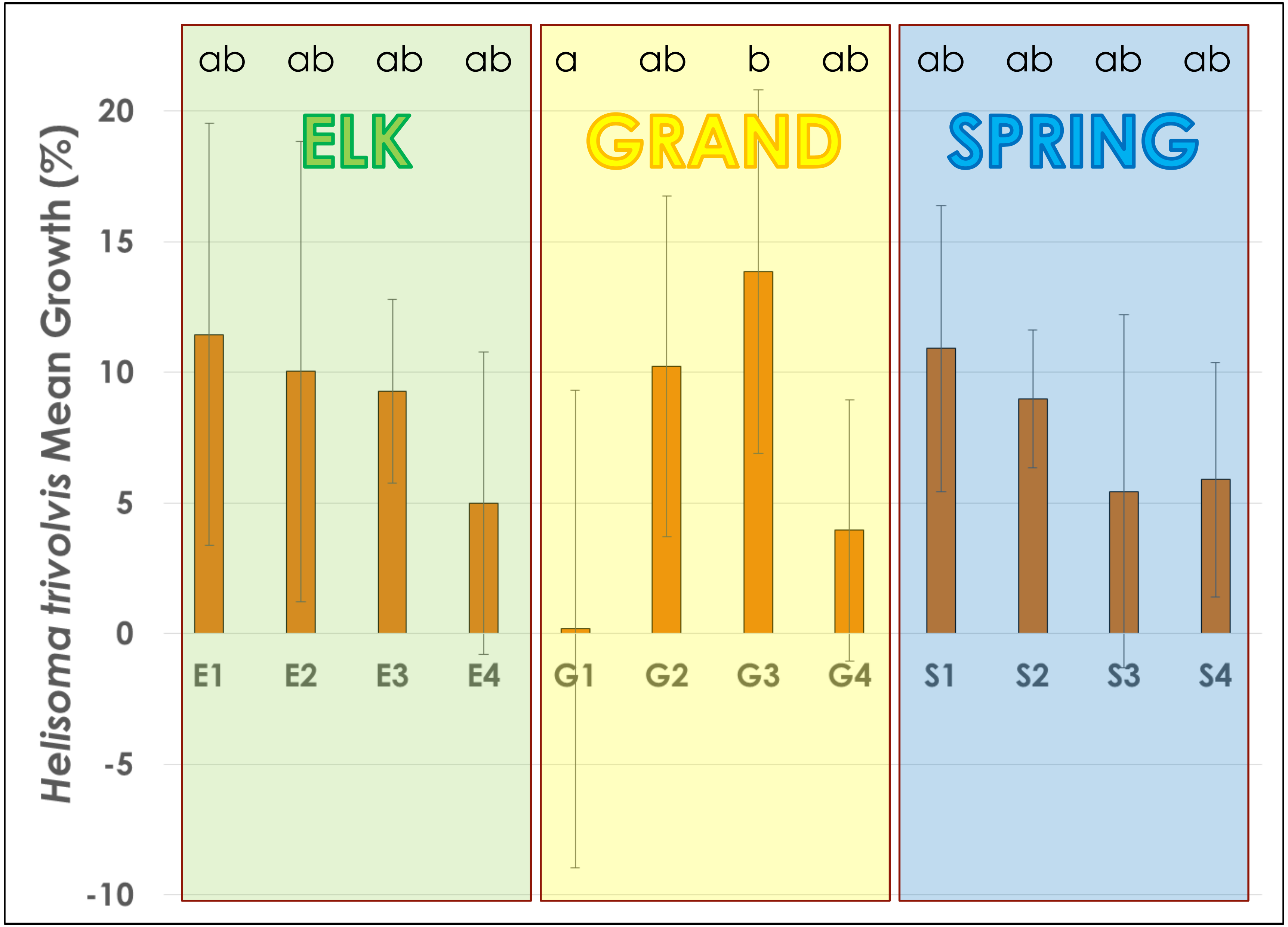
- No significant differences (a = 0.05)
- Most Survivors:
  - 100% (n = 39)
- Fewest Survivors:
  - 50% (n = 1)
- Average Survival:
  - 91%



Results – Disturbed Conditions

Survival Assessment

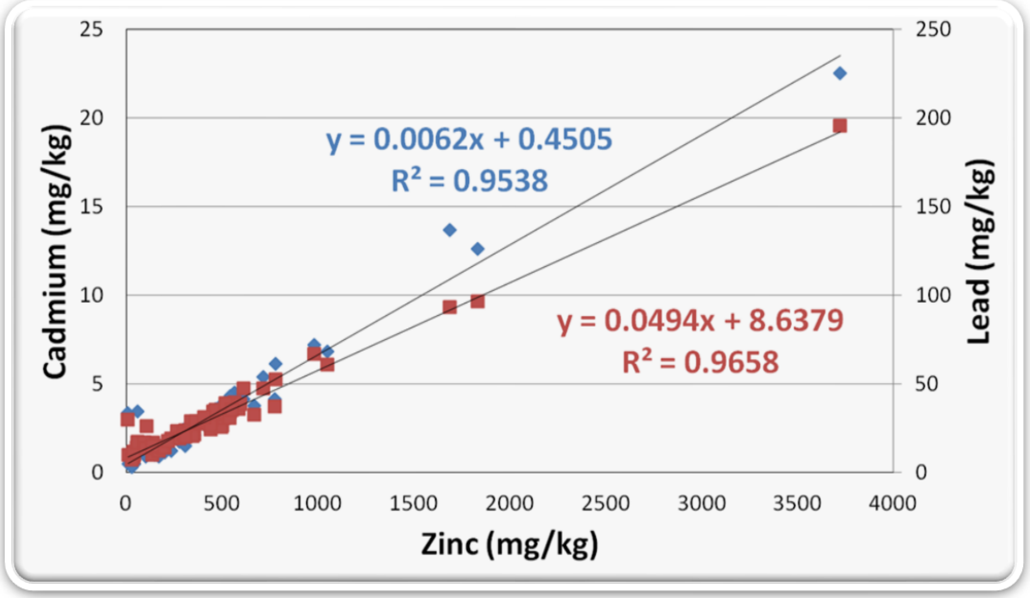
- No significant differences (a = 0.05)
- Most Survivors:
  - 100% (n = 64)
- Fewest Survivors:
  - 80% (n = 1)
- Average Survival:
  - 99%



Summary – Sediment Burdens

Grand Lake Shallow Sediment Concentrations

- Cadmium, lead and zinc were detected in all sediments.
- Elevated concentrations are distributed in the northern reaches of Grand Lake.
- Only a small percentage of sites exceeded TSMD-specific PEC values.
- Cadmium, lead and zinc sediment concentrations are strongly correlated across all sediment samples.
    - Distribution is seems to be dependent on sediment (re)suspension and deposition.



Summary – Biological Effects

Survival and Growth Assessments

- No significant differences in mortalities were observed for either amphipods or snails
- The only differences in growth were observed during the disturbance treatment.

Bioavailability

- Expected to be low based on lake water chemistries

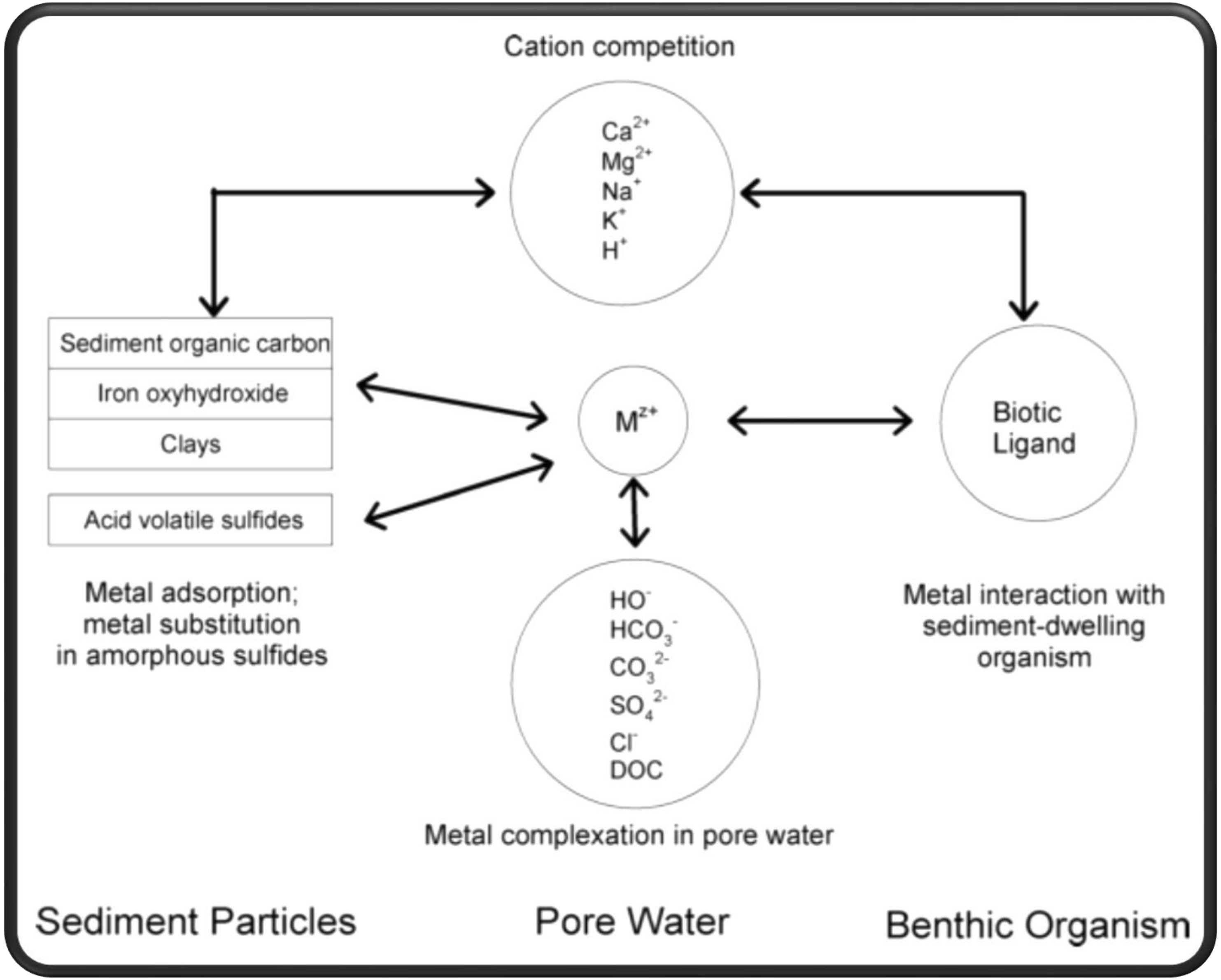
Biotic Ligand Model

Model Framework

- Free Ion Activity Model (1993)
  - Chemical model
- Gill Model (1996)
  - Physiological and toxicological model

Key Points

- Exposure at target tissues must occur to induce a toxic effect
- Competition at biological active sites may reduce overall exposure

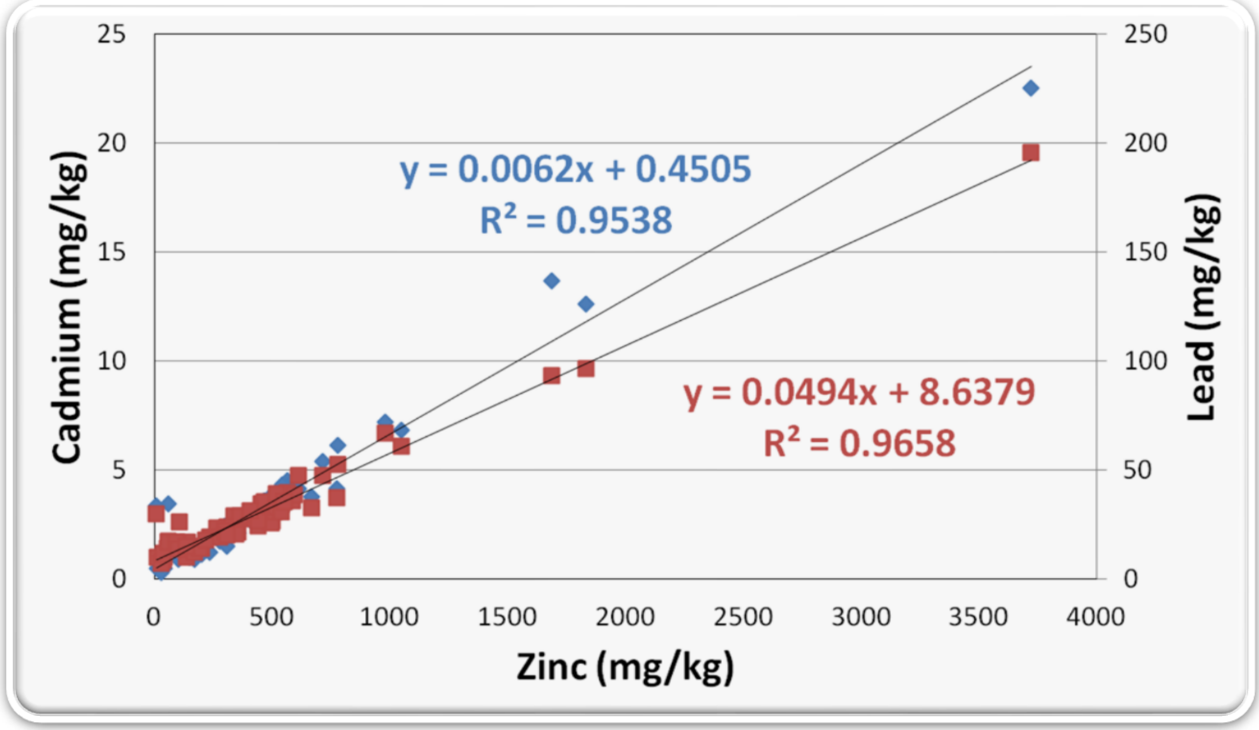


Di Toro et al. (2005)

Conclusions

Implications

- Despite elevated sediment concentrations, no significant adverse affects to aquatic organisms have been observed.
- Particle (re)suspension events are of greatest concern for shallow water areas (≤ 6 m depth) on the Spring River.
- Provides a local assessment of trace metal bioavailability, toxicity and the appropriateness of TSMD-specific PECs.



Trace Metal	General Thresholds (mg/kg)		TSMD-Specific (mg/kg)
	TEC	PEC	PEC
Cadmium	0.99	4.98	11.1
Lead	35.8	128	150
Zinc	121	459	2083

MacDonald et al. (2000); MacDonald et al. (2009)

Current Project Trajectory

Impending Data

- Trace Metal Analysis
  - Sediment samples
  - Overlying water samples
  - Pore water samples (peepers)
  - Accumulation in snail tissues

Acknowledgments

Support Team

- William Mimbs (OSU)
- Jessica Morrison (OSU)
- Ryan Sherman (OSU)
- Adam Simpson (OSU)

Questions?

"Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy."
-Paracelsus

Sediment Quality Guidelines

Trace Metal	General Thresholds (mg/kg)		TSMD-Specific (mg/kg)
	TEC	PEC	PEC
Cadmium	0.99	4.98	11.1
Lead	35.8	128	150
Zinc	121	459	2083

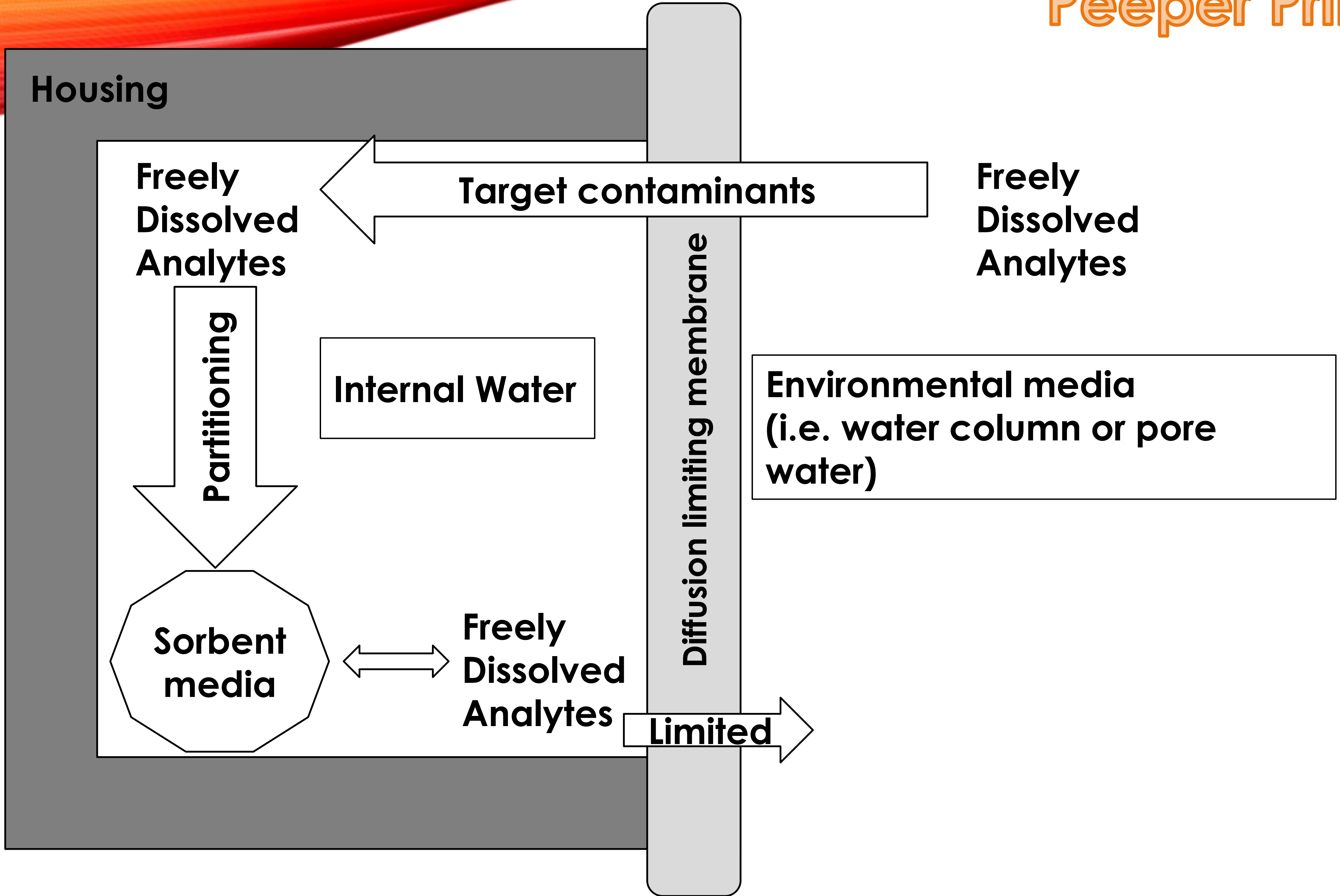
The Dudding Model:

- $\sum$ PEC-$Q_{Cd,Pb,Zn}$
- Only need to measure Cd, Pb, and Zn

$$\frac{[\,Cd\,]}{4.98} + \frac{[\,Pb\,]}{128} + \frac{[\,Zn\,]}{459} < 7.92$$

MacDonald et al. (2000); MacDonald et al. (2009)

Peeper Principles



Uptake Kinetics