Integrating mesocosm experiments and field data to support development of water quality criteria

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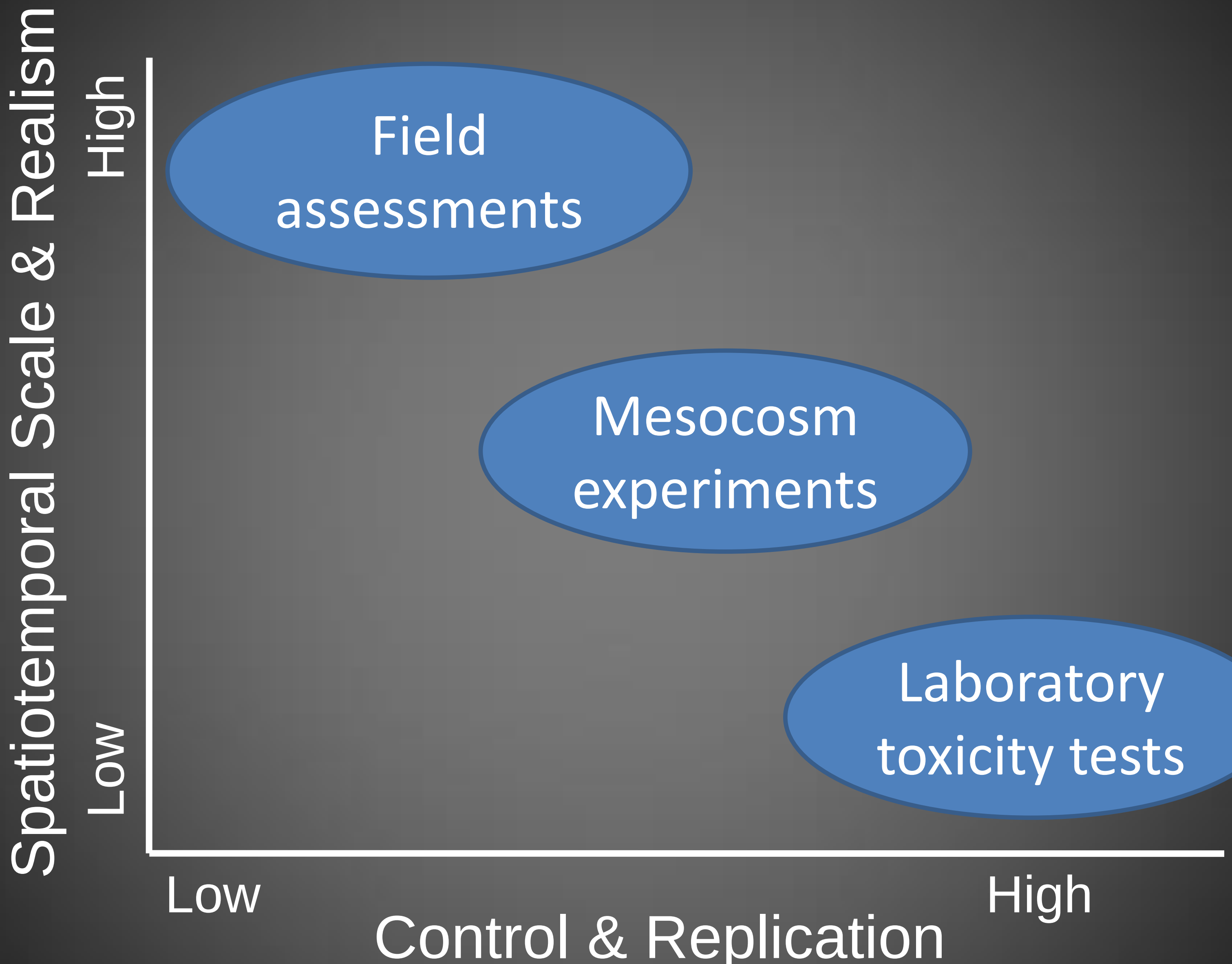


Spatiotemporal Scale & Realism
High
Low
Field assessments
Mesocosm experiments
Laboratory toxicity tests
Low
High
Control & Replication

Criticism of Small-Scale Experiments in Ecological Research

"Microcosm experiments have limited relevance in community and ecosystem ecology"

"Irresponsible for academic ecologists to produce larval microcosmologists"

- Provide fast results: good for career development
- Keep faculty on campus under the watchful eye of administrators

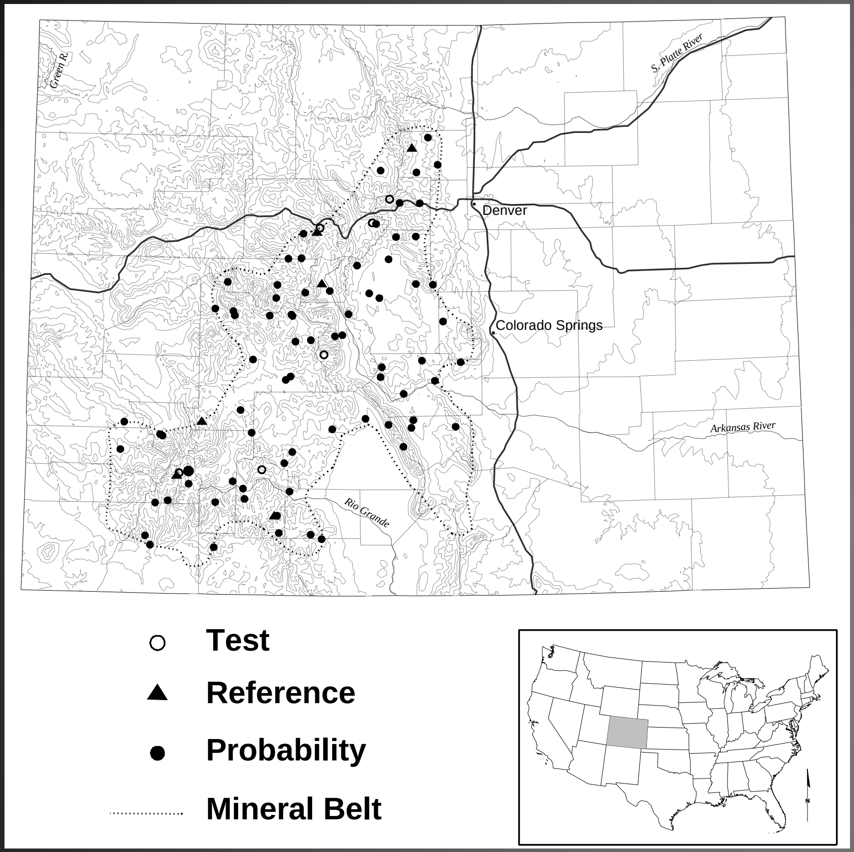
Carpenter, 1996

Overview

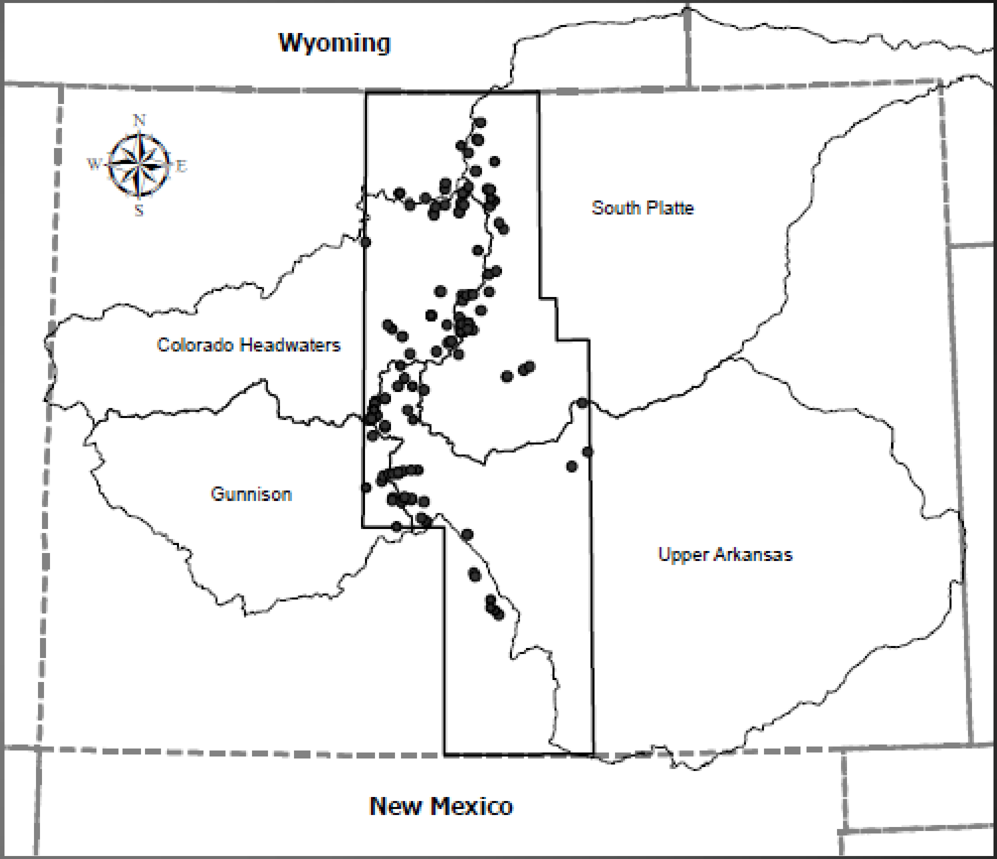
- Differences between field & lab responses to contaminants
- A few hypotheses to explain these differences
- Application of mesocosm experiments to test these hypotheses and to support the development of water quality criteria

Spatially extensive and long-term surveys of metal-contaminated streams in Colorado

EPA EMAP (n = 95)



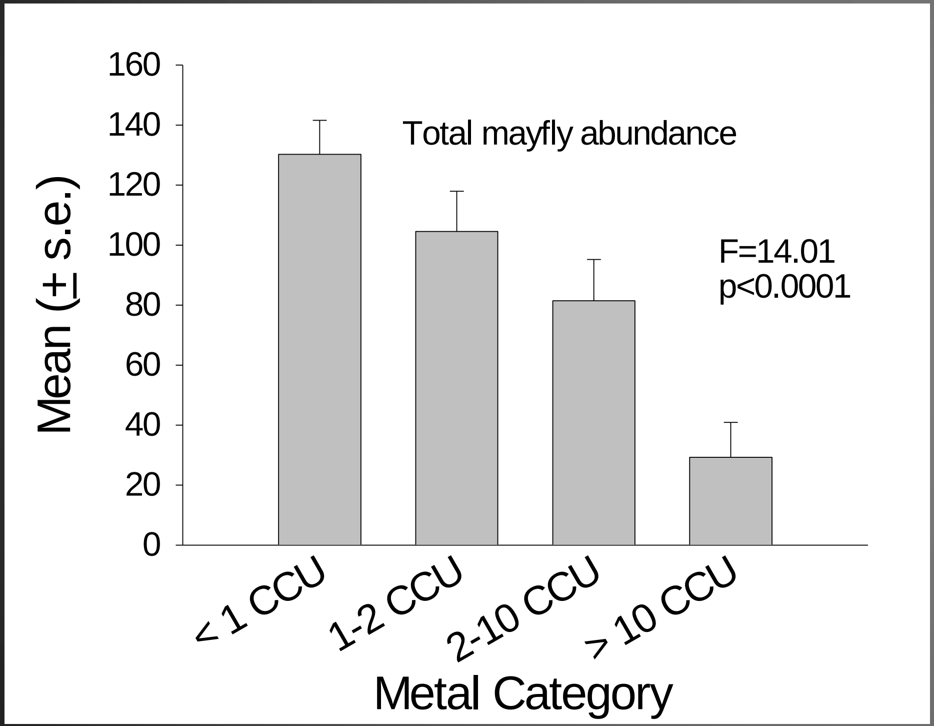
USGS & CSU (n = 154)

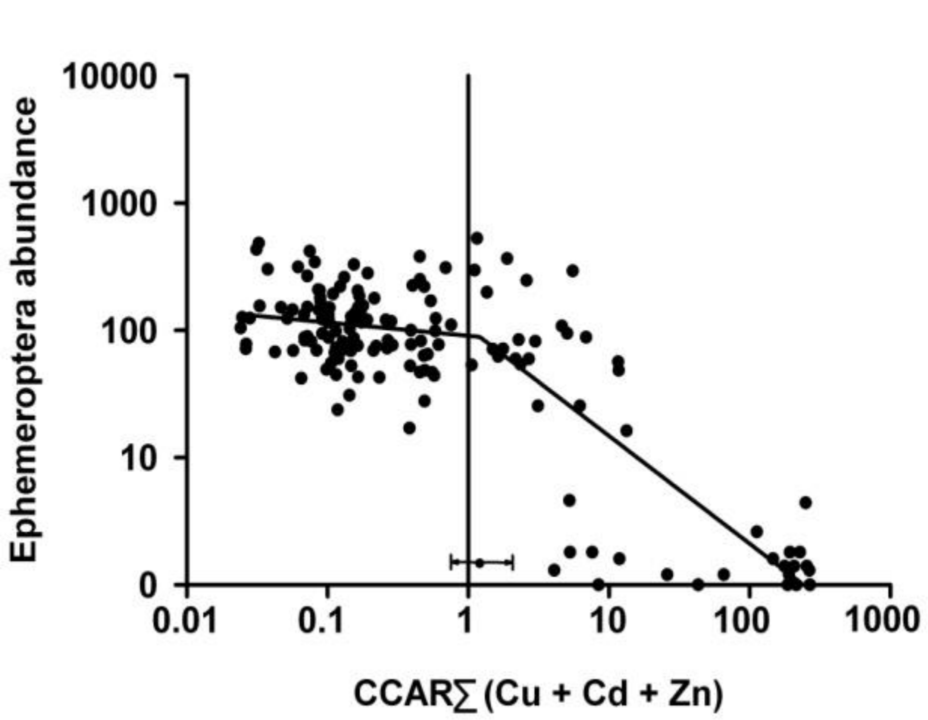


Quantify relationship among metals, aquatic insect communities and other environmental variables

Sensitivity of aquatic insects (especially mayflies)

Highly significant effects on mayflies at relatively low metal concentrations





Clements et al. 2000

Schmidt, Clements & Cade, 2012

But, lab toxicity data do not reflect this sensitivity

Copper

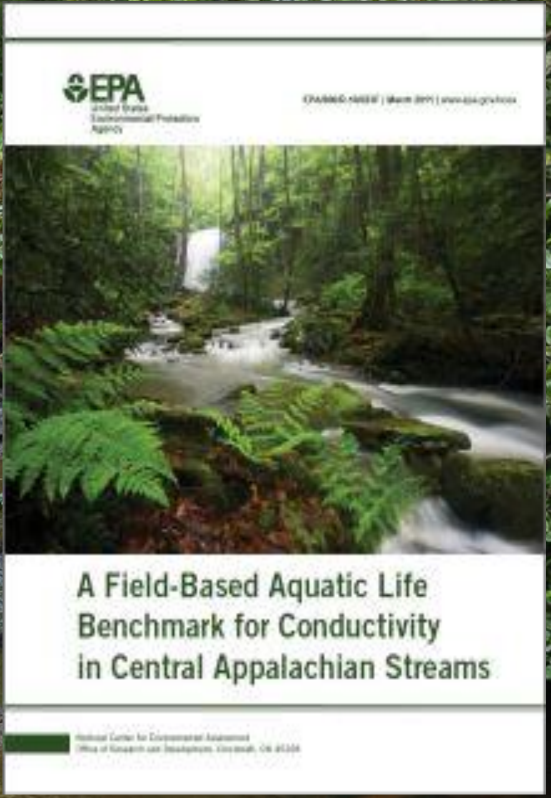
Species	LC_{50}
Ephemerella subvaria	320 µg/L
Drunella grandis	201 µg/L
Stenonema sp.	453 µg/L
Drunella grandis	190 µg/L
Rhithrogena hageni	137 µg/L
Isonychia bicolor	223 µg/L

Zinc

Species	LC_{50}
Ephemerella sp.	> 68.8 mg/L
Cinygmula sp	68.6 mg/L
Drunella doddsi	> 64.0 mg/L
Rhithrogena hageni	50.5 mg/L
Baetis tricaudatus	11.6 mg/L
Baetis tricaudatus	> 2.9 mg/L

Warnick and Bell 1969; Goettl et al. 1972; Dobbs et al. 1994; Brinkman & Johnston 2008; Brinkman et al. 2012; Mebane et al. 2012

Similar patterns with major ions



Conductivity benchmark
→ 300 μS/cm

Source	Endpoint	Response (µS/cm)	Reference
Road salt (lab)	Insect survival & drift (96 h LC50)	3,526-10,000	Blasius & Merritt (2002)
Road salt (lab)	Insect survival (72 h LC50)	5,500-25,000	Kellford et al. (2003)
Salt mining (mesocosm)	Stream invertebrates (72 h survival)	5,000	Canedo-Arguelles et al. (2012)
Road salt (lab)	*Chironomus* survival & emergence (67 d)	5,000	Lob & Silver (2012)
MTM-VF (field)	Community composition of stream invertebrates	< 500	Pond et al. (2009)
MTM-VF (field)	Community composition of stream invertebrates	300	USEPA (2011) Cormier et al. (2013)

A few hypotheses to explain these differences

1. Interspecific interactions

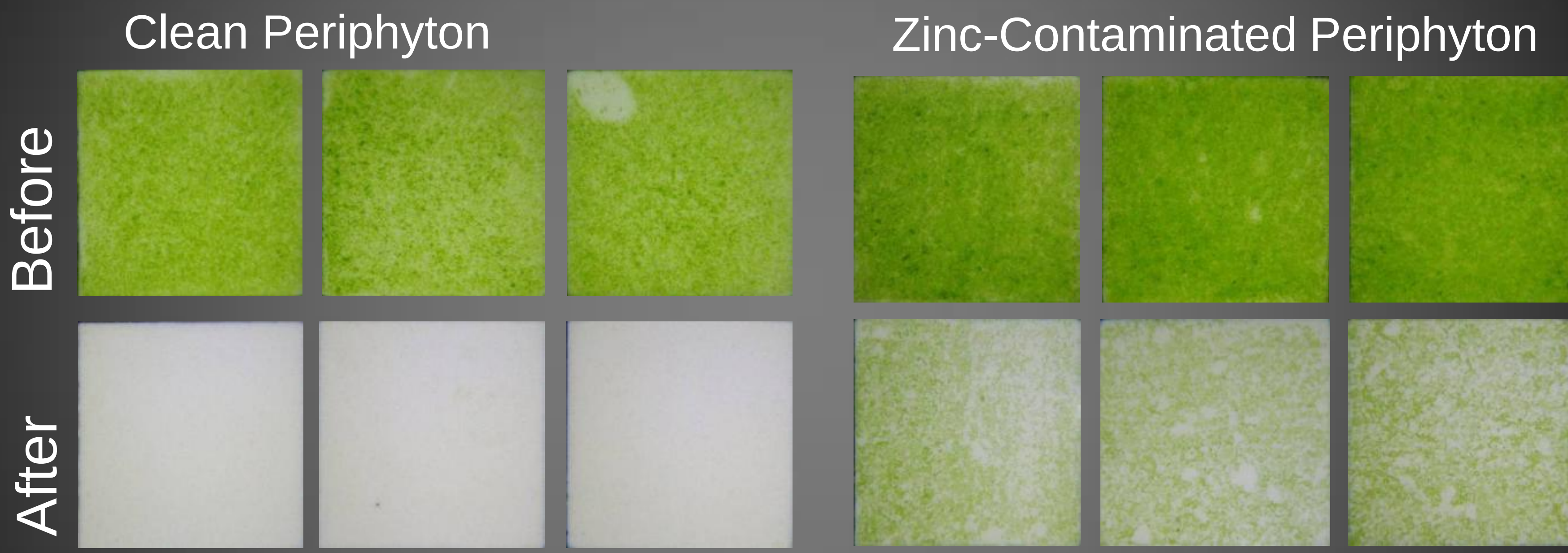
Metal exposure resulted in greater susceptibility of aquatic insects to predation

(Clements et al 1989; Kiffney 1996; Clements 1999)

2. Dietary exposure

(Irving, Baird & Culp 2003; Xie, Funk & Buchwalter 2010; Xie & Buchwalter 2011; Cadmus 2010)

Reduced Grazing on Zn-Contaminated Periphyton



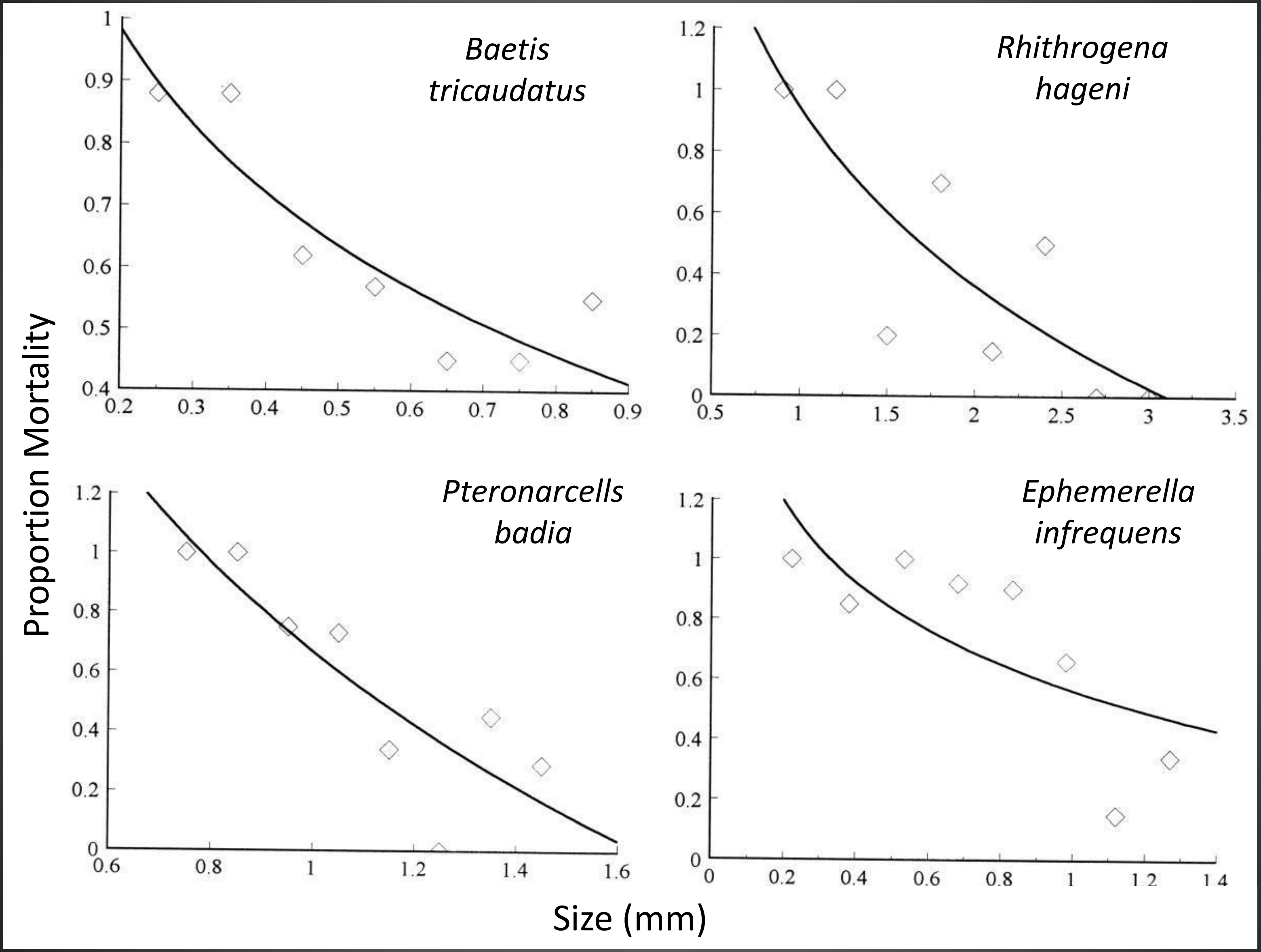
3. Short-term (96 h) experiments are inadequate for assessing effects of contaminants on aquatic insects

Species	Days required to reach steady state (Cd)
Rhithrogena	5588
Ephemerella	399
Rhyacophila	41

(Buchwalter et al. 2007)

4. Physical influences (Fe oxides)

5. Sensitivity of early instars to metals



Kiffney & Clements 1996

Laboratory experiments with early instar mayflies (*Neocloeon triangulifer)* exposed to major ions

Toxicant	Endpoint	Response (µS/cm)	Reference
Brine salt	Growth (20 d)	672	Johnson et al. (2015)
Reconstituted MMVF waters	Survival (35 d)	800-1300	Kunz et al. (2013)
NaCl	Survival to pre-emergent nymph stage (23 d)	939	Soucek and Dickinson (2015)

Using mesocosm experiments to support development of water quality criteria

- Establish concentration-response relationships
    - Identify “safe” concentrations (e.g., EC20s)

- Examine multiple stressors & stressor interactions

- Measure nontraditional endpoints (e.g., drift, metabolism)

- Investigate context dependency

Stream Microcosm Experiments

Date	Stressor
Oct 1991	Zn
Jul 1992 & Sept 1992	Cd, Cu, Zn
Nov 1993 & Aug 1996	Zn
Aug 1997	Cd, Cu, Zn
Oct 1998	Cd, Zn
Nov 1999	Cd, Cu, Zn
Aug & Oct 2000	Cd, Cu, Zn
Jul 2002 & May 2003	Cd, Cu, Zn
Sep 2003	Zn
Aug 2003	Cd, Cu, Zn
September 2007	Cu
October 2007	Cu, Zn
October 2010 & May 2012	Fe
July, 2011 & 2012	Fe, Cu, Zn
July 2012	Cu + Hardness
Oct 2013 to Aug 2014	Major ions
Aug & Sept 2014	Activated carbon

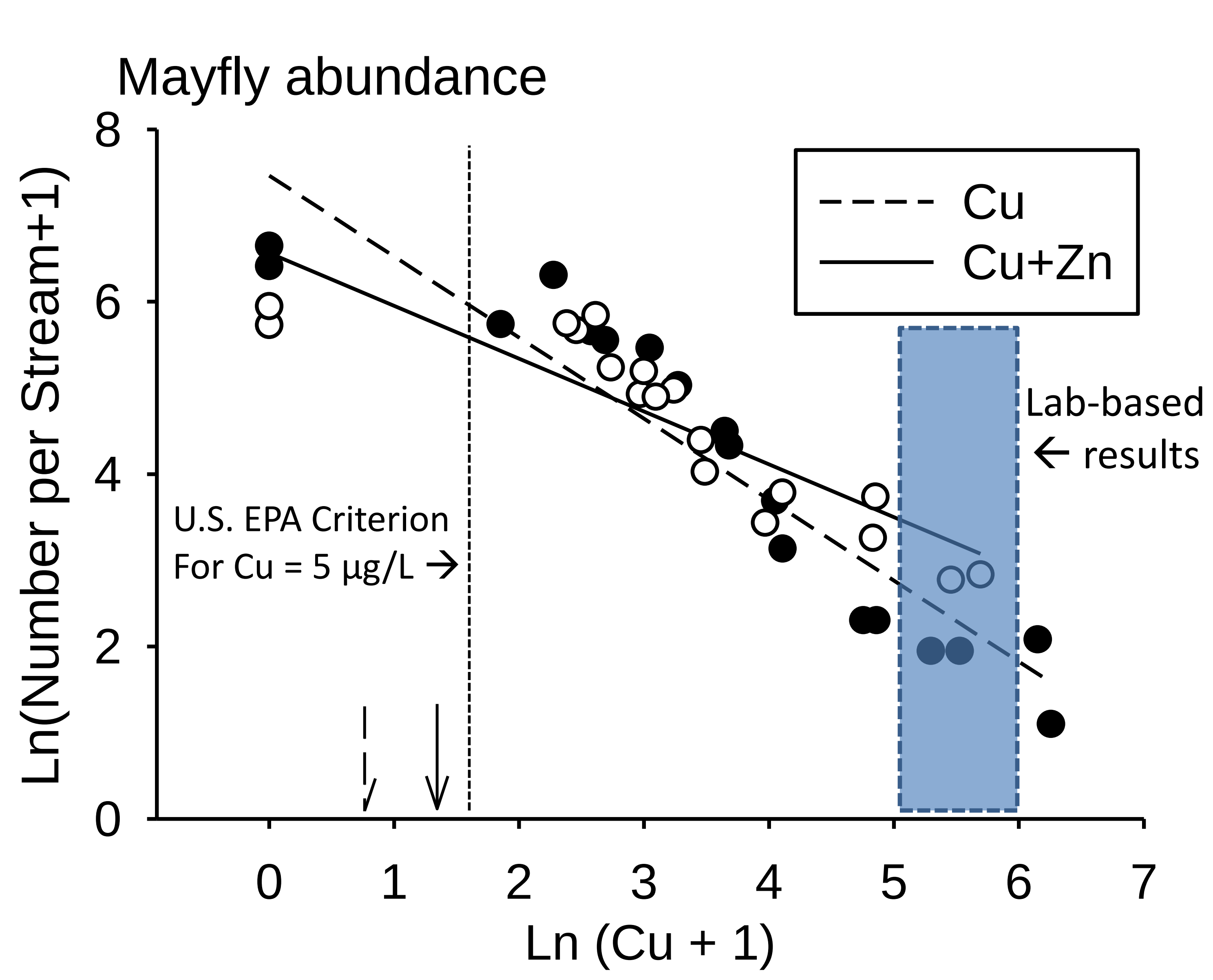
Variables

- Season
- Concentration
- Metal combinations
- Other stressors
- Source of community

Endpoints

- Survival
- Size-specific mortality
- Metal uptake
- Community comp.
- Drift & immigration
- Community metabolism
- Leaf decomp.

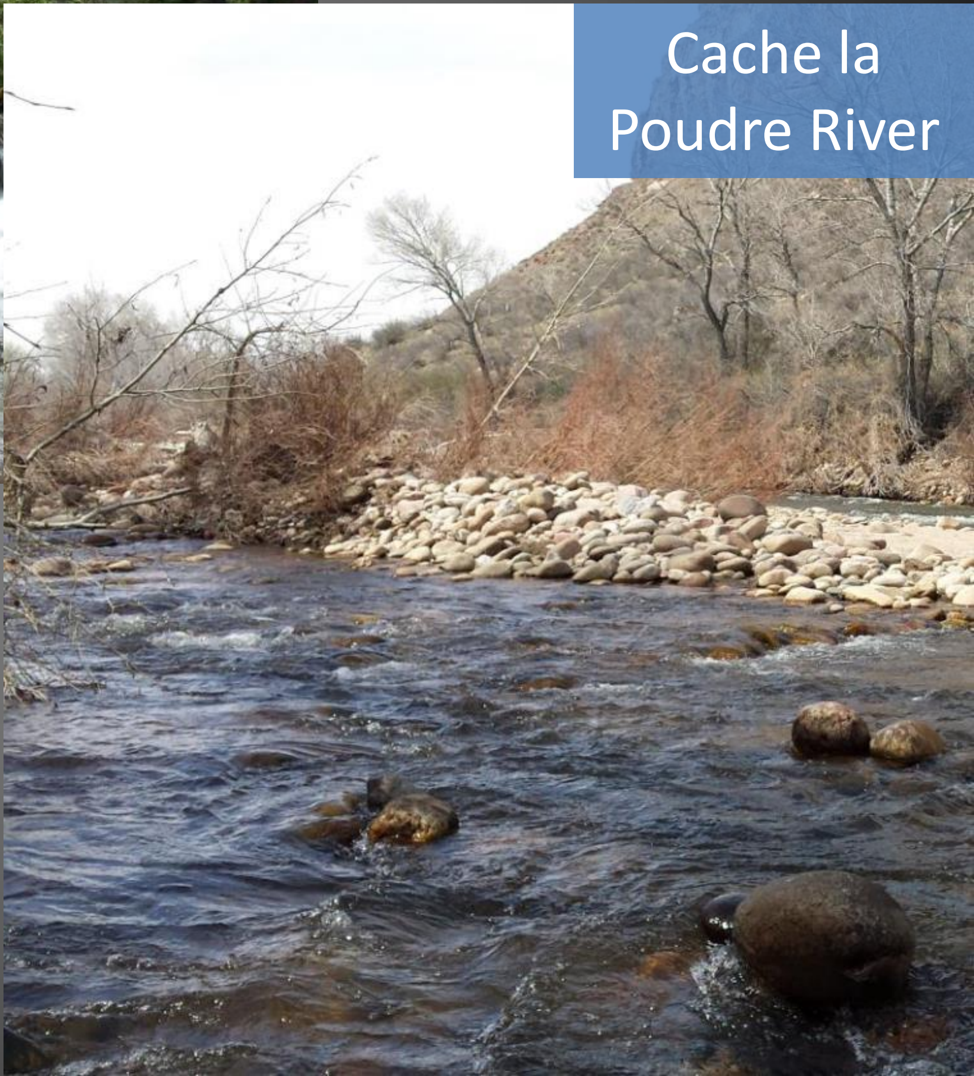
Interactions among metals



Clements et al. 2013

Effects of major ions on benthic communities

South Fork of the Michigan River

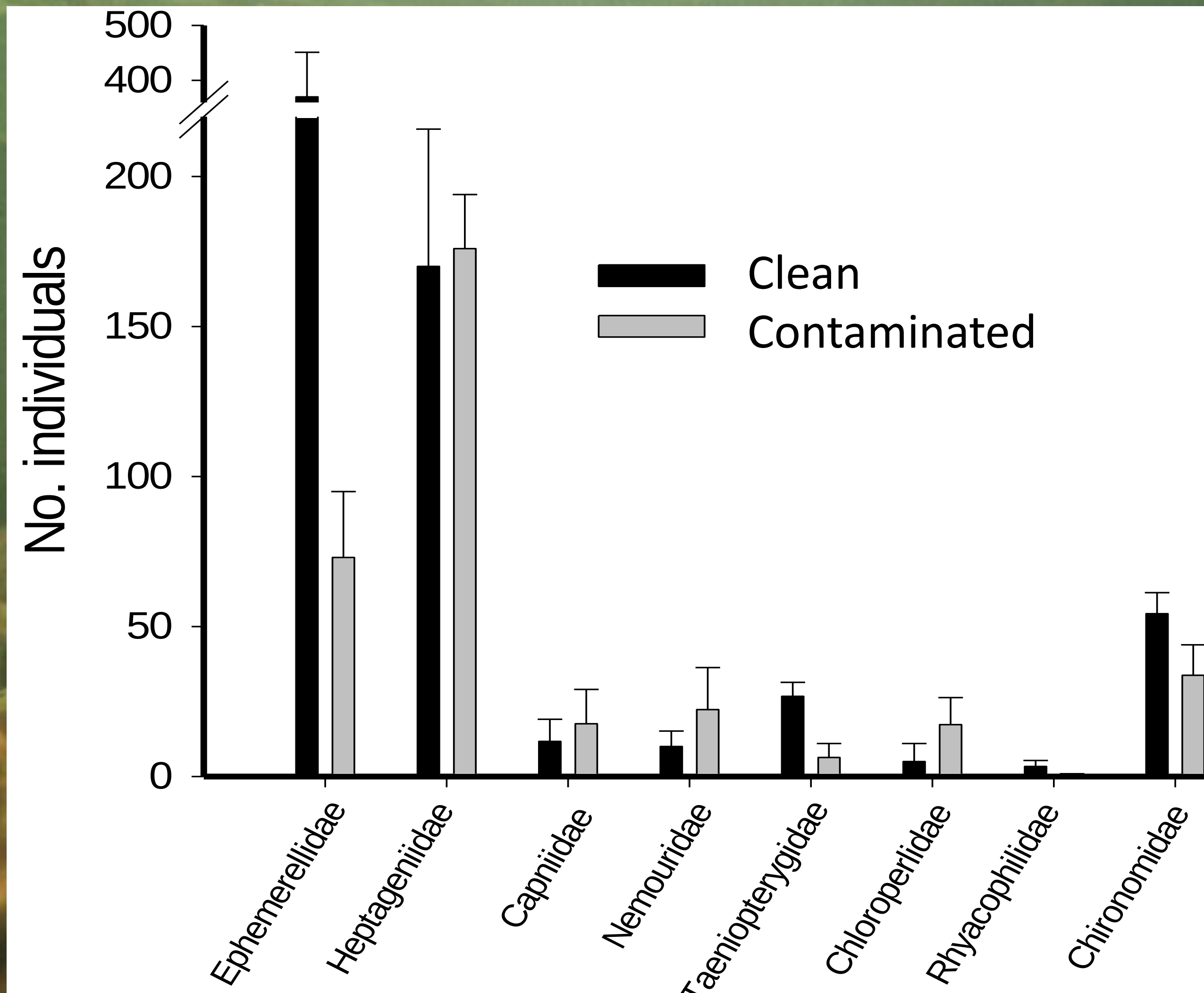


Cache la Poudre River

4 Mesocosm Experiments:

- $NaHCO_3$
- $MgSO_4$
- NaCl (2 experiments)

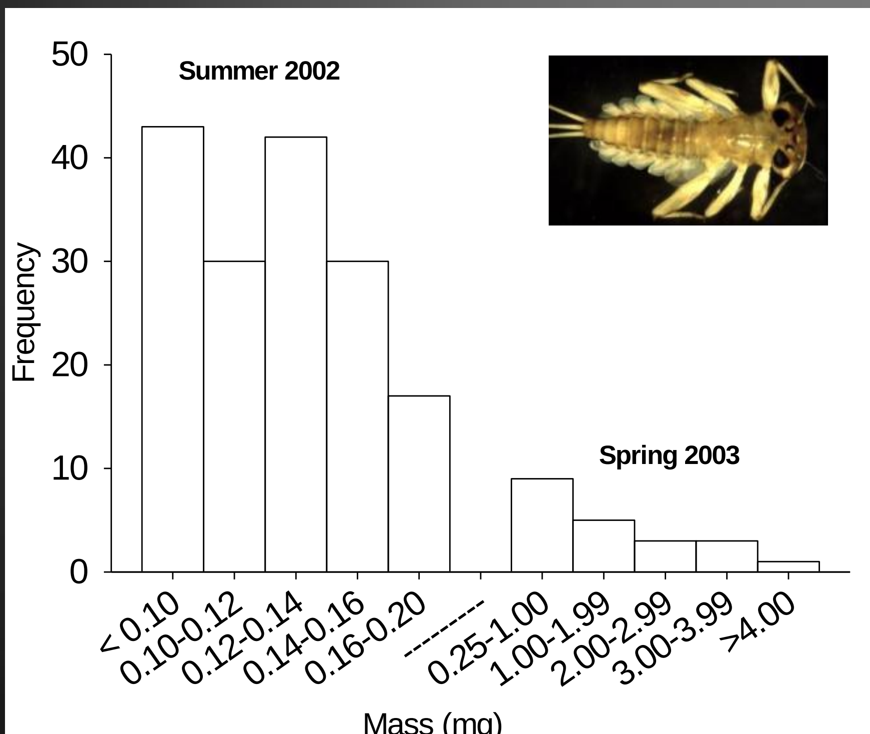
Colonization of Clean & Contaminated Substrate in the Animas River, CO



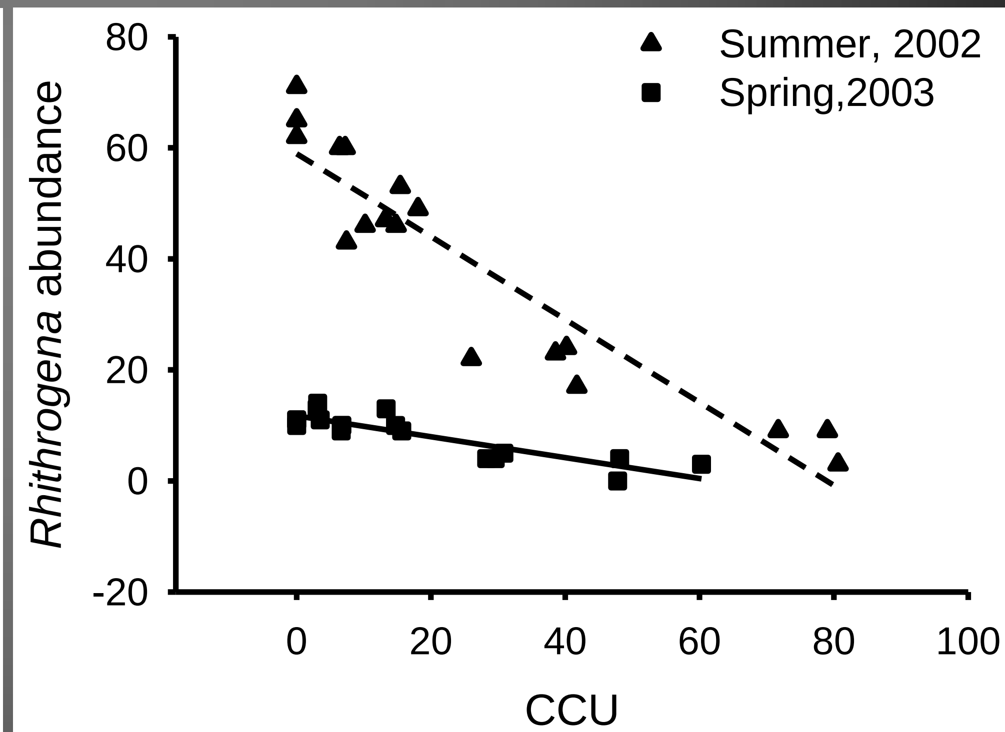
Courtney & Clements 2002

Seasonal Variation in Sensitivity to Metals

Size distribution of *Rhithrogena* in summer & spring



Responses to metals in summer & spring



Clark & Clements 2006

Community Metabolism (light/dark O_2 measurements)

Context-dependent Responses to Contaminants


Sub-alpine
stream


Foothills
stream

Use of Mesocosm Experiments to Support the Development of Water Quality Criteria

- Ecologically realistic conditions & endpoints
- Test hypotheses to explain discrepancies between lab & field
- Essential for stressors that show little direct toxicity in the lab (e.g., nutrients, Fe)

Thanks!

>100 CSU graduate & undergraduate students

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