Minimum data requirement for developing water quality criteria: Use of toxicity data from under-represented organisms

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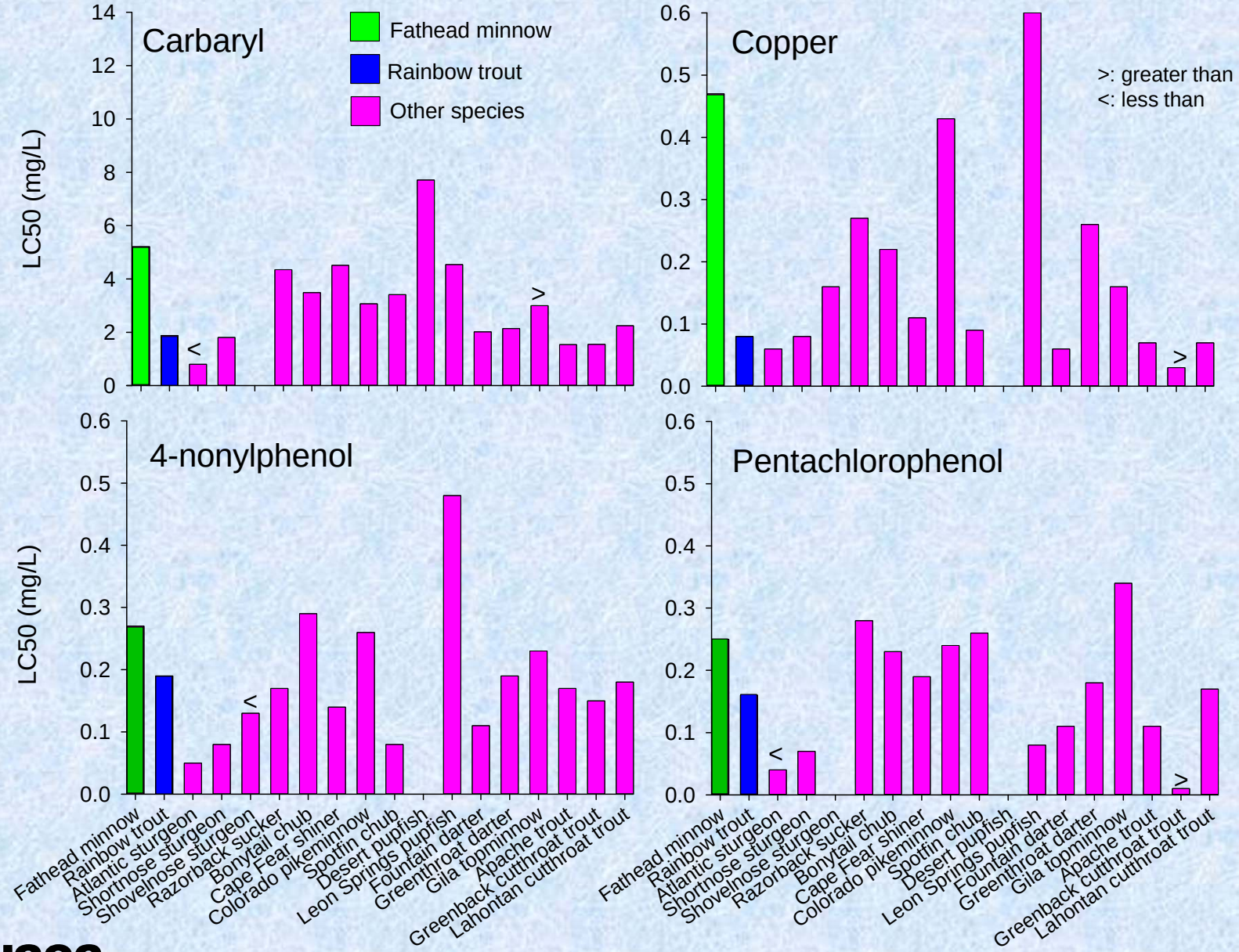
Invited expert meeting on revising USEPA's guidelines for deriving aquatic life criteria, September 14-16, 2015, Arlington, VA

U.S. Department of the Interior
U.S. Geological Survey

Overview

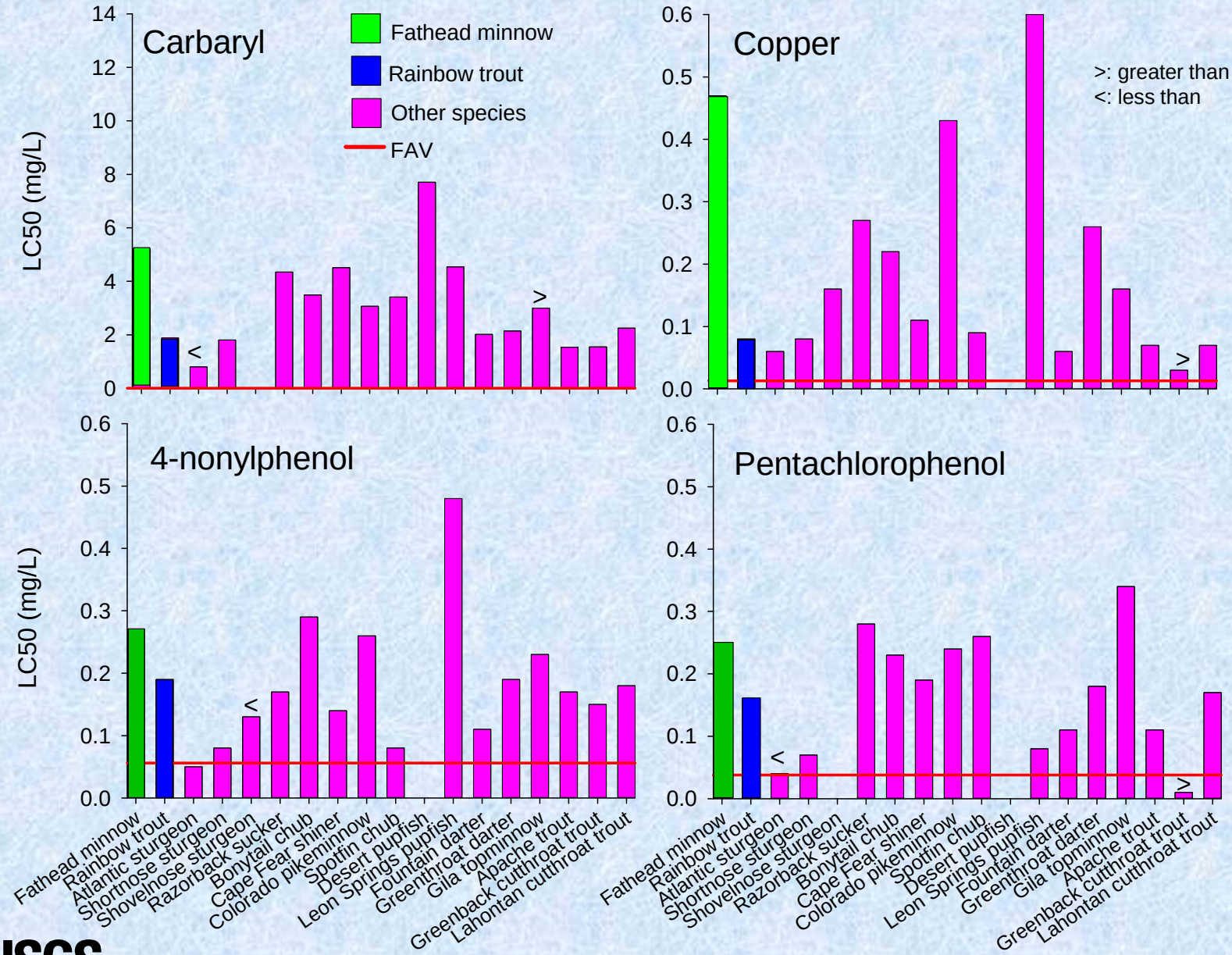
- Relative sensitivity of listed or under-represented fish and commonly tested fish
- Relative sensitivity of listed or under-represented invertebrates and commonly tested invertebrates
- Relative sensitivity of freshwater mussels and other freshwater organisms
- Use of mussel toxicity data for developing water quality criteria (WQC)

Is a fish a fish? **Acute toxicity of chemicals to 2 commonly tested fish and 16 federally or state endangered, threatened, and candidate fish (Dwyer et al. 2005)**



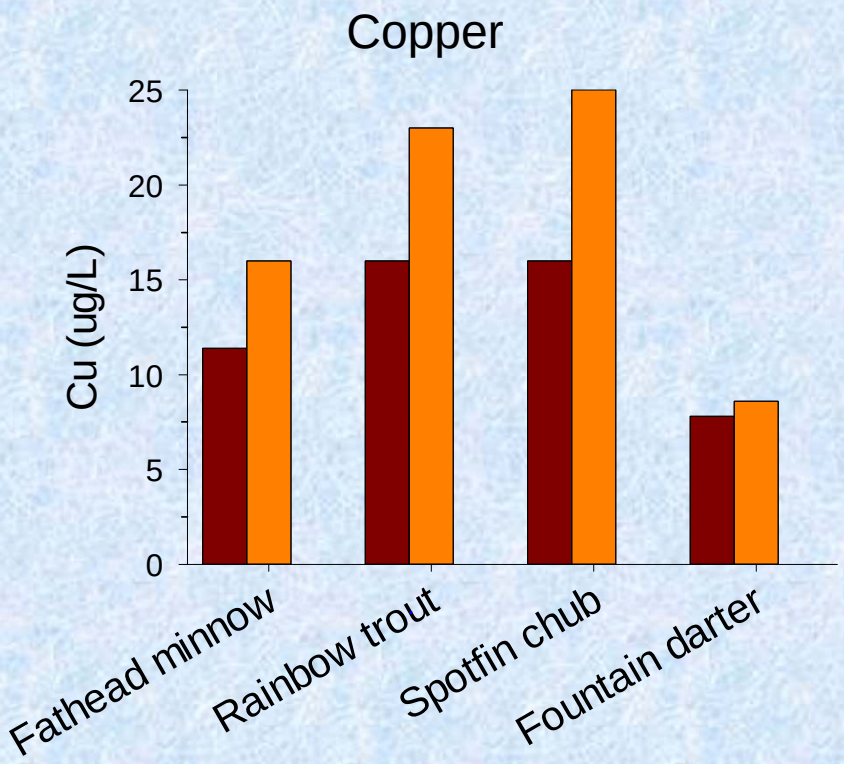
USGS

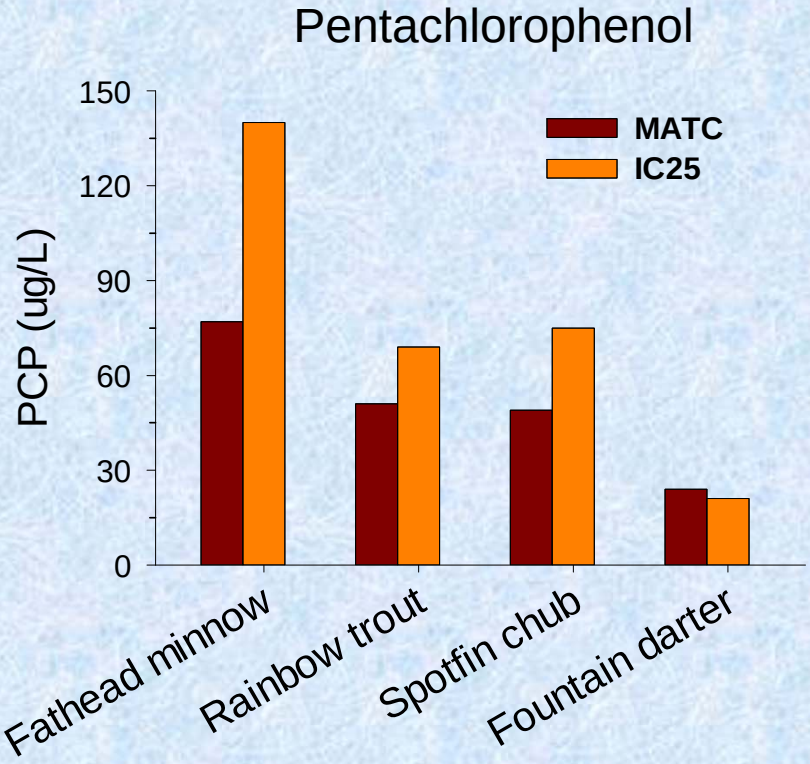
Acute toxicity of chemicals to the commonly tested fish and federally or state listed fish, compared to final acute value (FAV) in current USEPA WQC



USGS

Chronic toxicity of copper and pentachlorophenol to 2 commonly tested fish and 2 federally endangered or threatened fish (Besser et al. 2005)





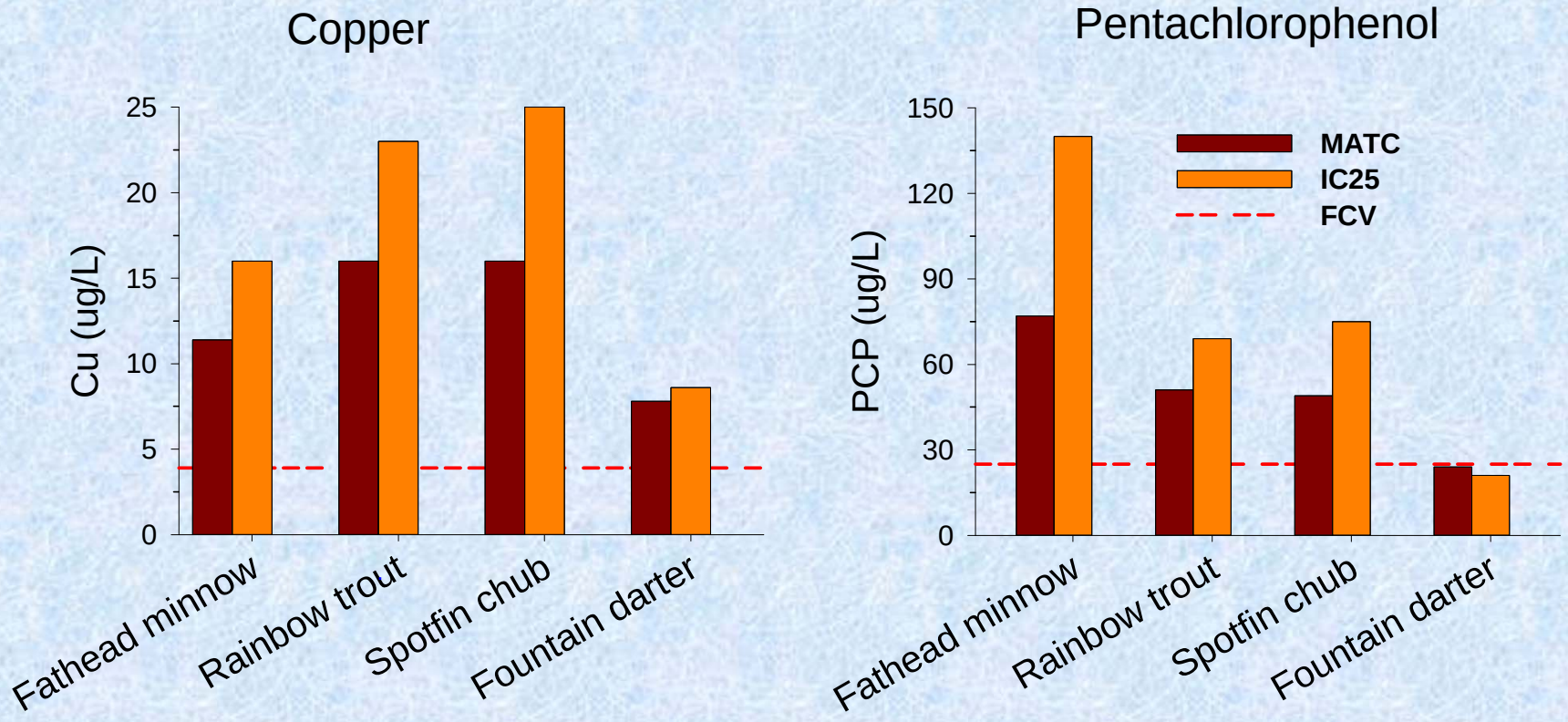
MATC: Maximum Acceptable Toxicant Concentration. IC25: 25% Inhibition Concentration

Fountain darter (*Etheostoma fonticola*), a small freshwater fish only in two rivers in Texas

Spotfin chub (*Erimonax monachus*), a cyprinid fish in the Tennessee River watershed

USGS

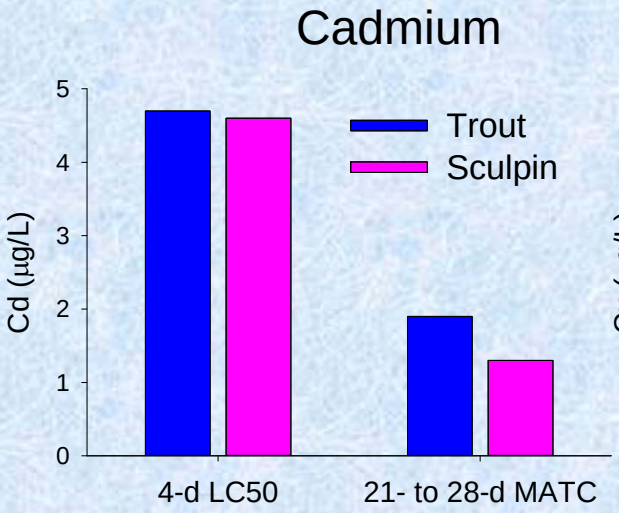
Chronic toxicity of copper and pentachlorophenol to the commonly tested fish and federally listed fish, compared to final chronic value (FCV) in current USEPA WQC

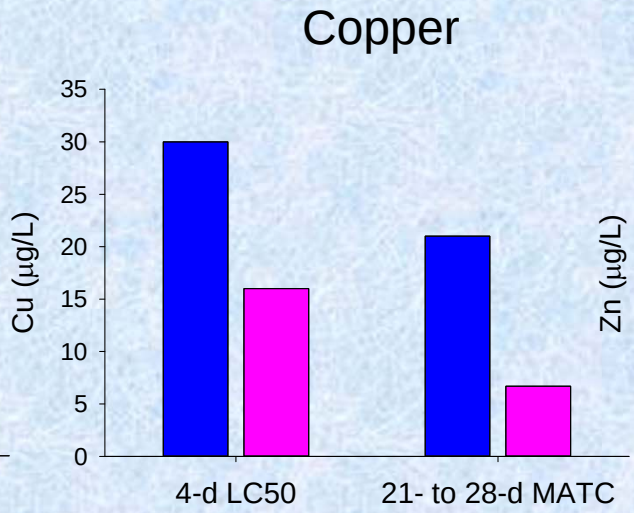


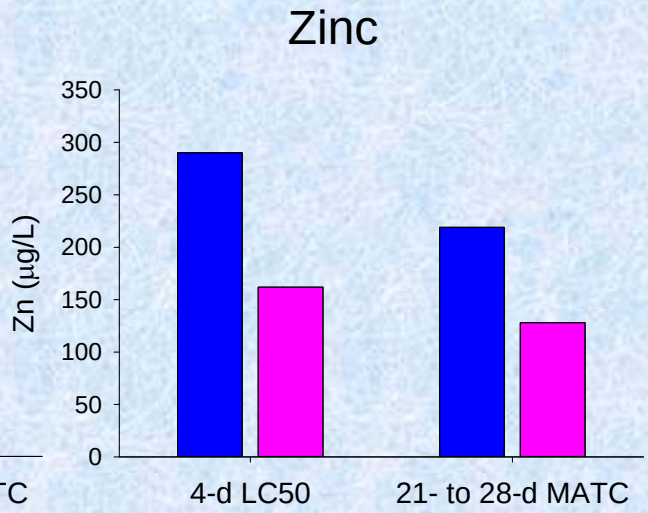
MATC: Maximum Acceptable Toxicant Concentration. IC25: 25% Inhibition Concentration

USGS

Acute and chronic toxicity of cadmium, copper, and zinc to rainbow trout and mottled sculpin (Besser et al. 2007)



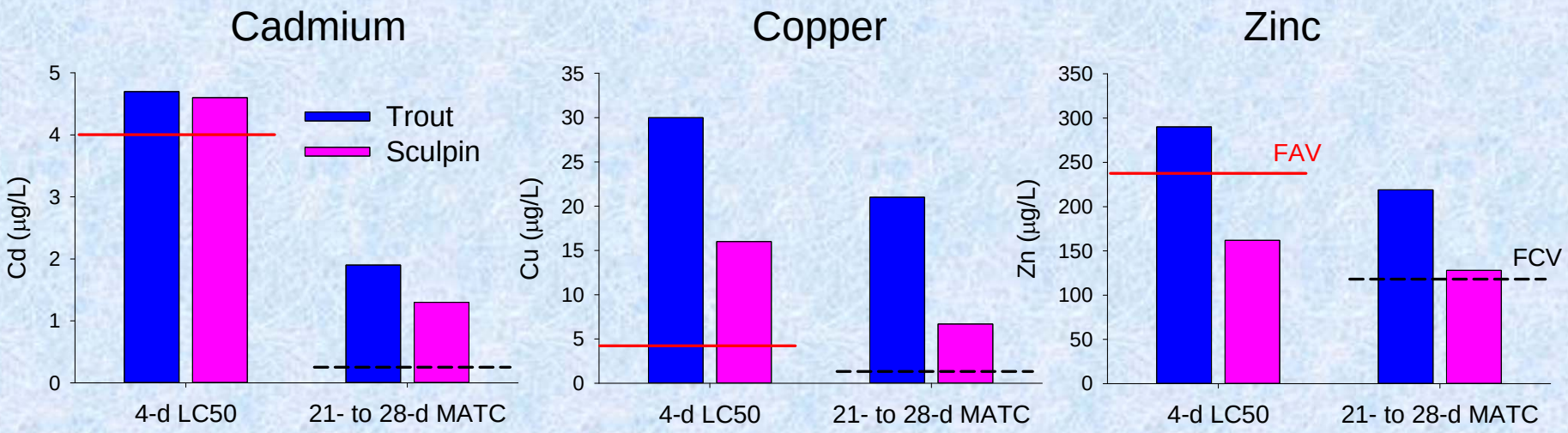




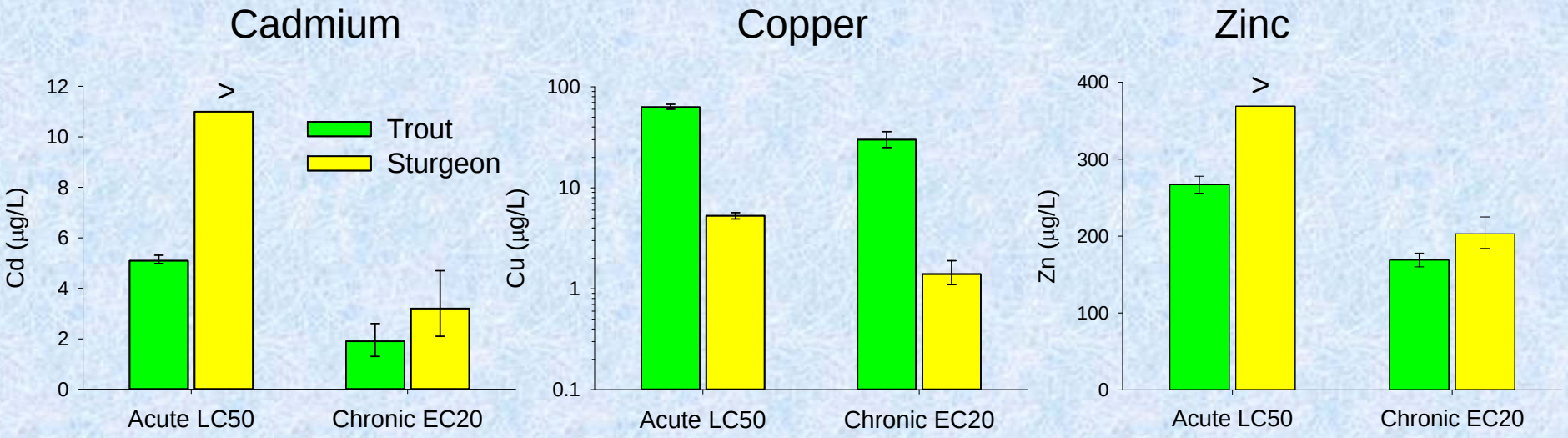
Mottled sculpin (*Cottus bairdii*), a freshwater fish (family Cottidae) found widely throughout North America

USGS

Acute and chronic toxicity of cadmium, copper, and zinc to rainbow trout and mottled sculpin, compared to final acute value (FAV) and final chronic value (FCV) in USEPA WQC



Acute and chronic toxicity of cadmium, copper, and zinc to rainbow trout and white sturgeon (Wang et al. 2014)

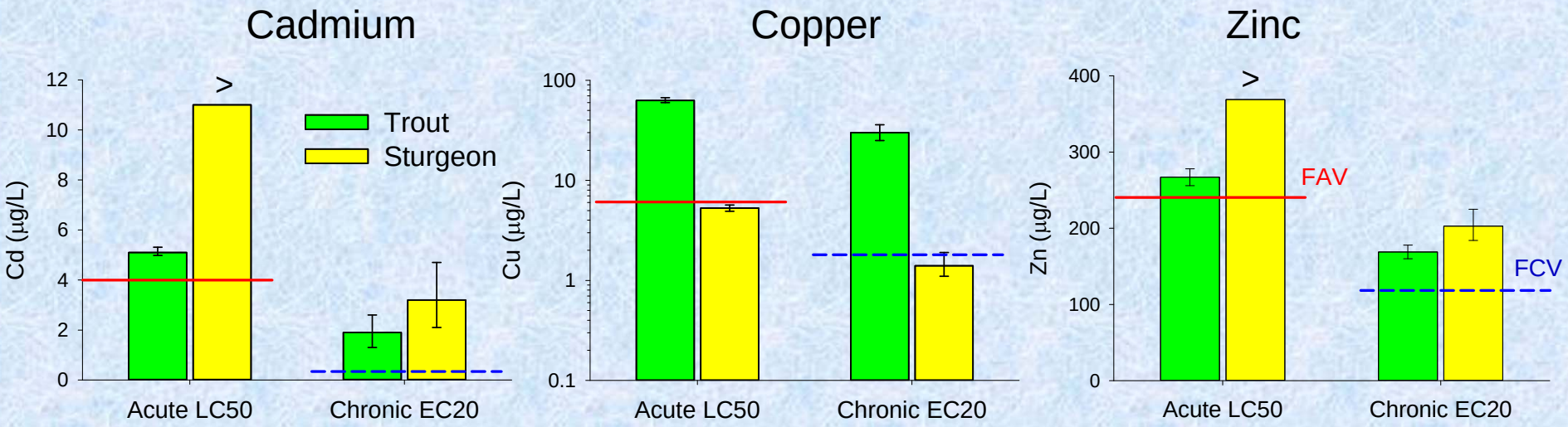


>: greater than. Error bar: 95% confidence limits

White Sturgeon (*Acipenser transmontanus*), lives along the west coast of North America, listed as threatened species in Canada; the Kootenai River white sturgeon listed as endangered species in the United States

USGS

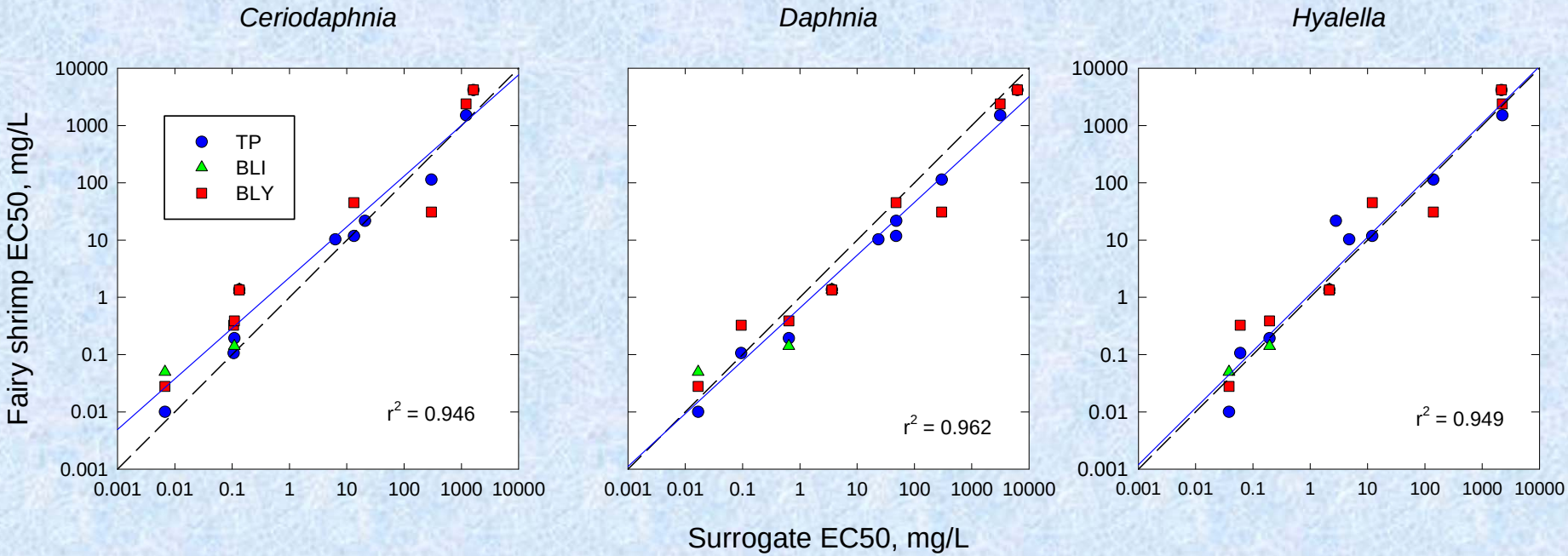
Acute and chronic toxicity of cadmium, copper, and zinc to rainbow trout and white sturgeon, compared to final acute or chronic value in USEPA WQC



>: greater than. Error bar: 95% confidence limits

USGS

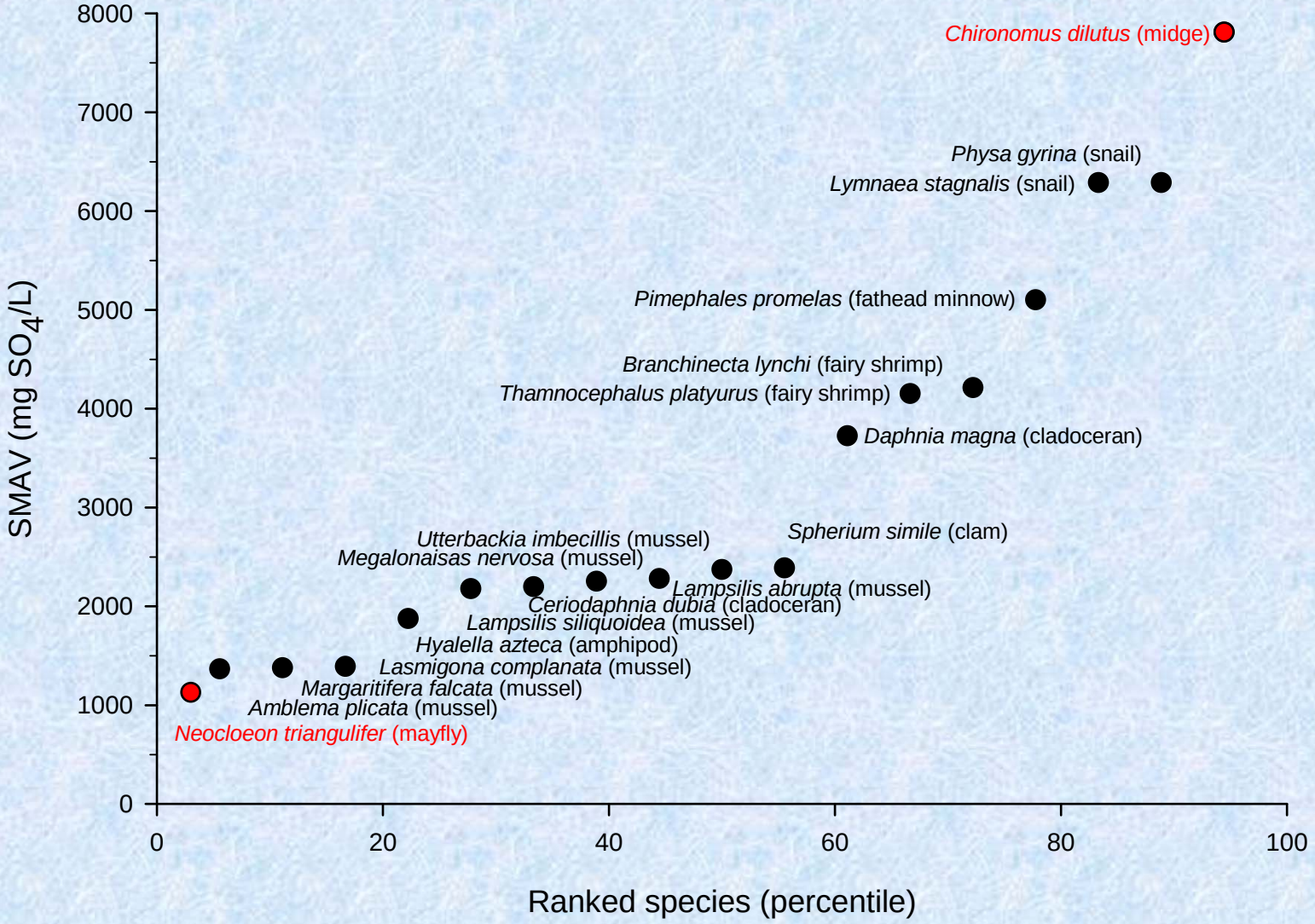
Is a crustacean a crustacean? Relative sensitivity of fairy shrimp (TP=*Thamnocephalus platyurus*, BLI=*Branchinecta lindahli*, and BLY=*B. lynchi)* and commonly tested crustaceans (*Ceriodaphnia dubia, Daphnia magna, Hyalella azteca*) in acute exposures to 10 chemicals (Ivey et al. in prep.)



Fairy shrimp (Branchiopoda: Anostraca) are relatively large crustacean zooplankton (>10 mm), restricted almost entirely to temporary wetlands worldwide. *B. lindahli* is federally endangered species.

USGS

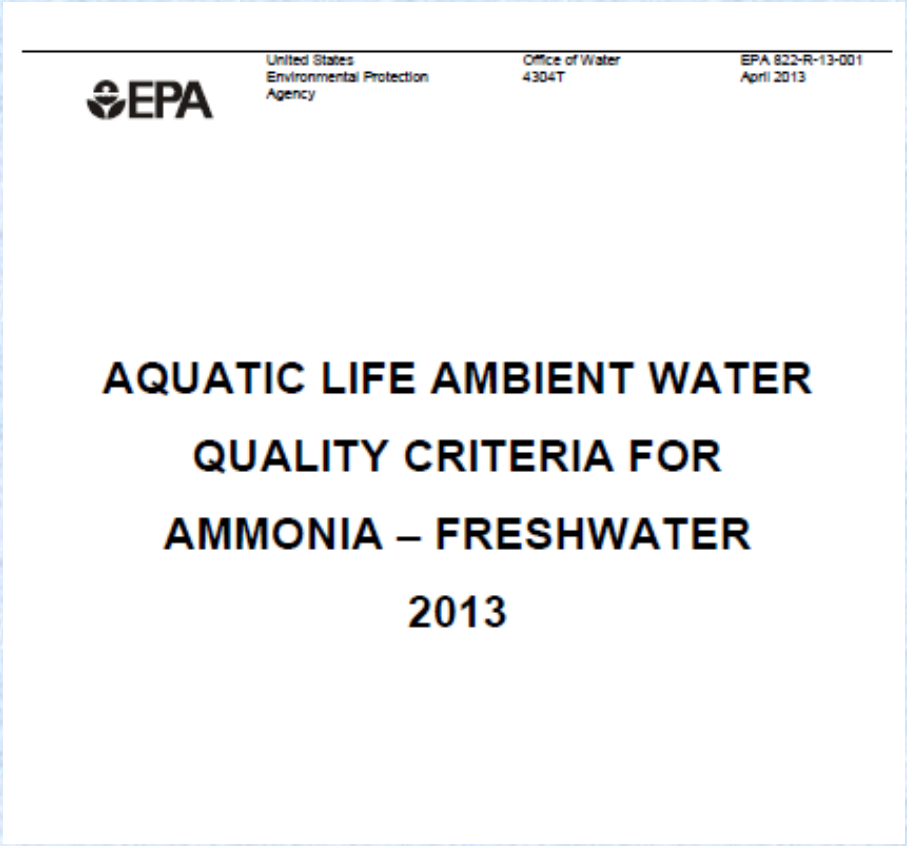
Is an insect an insect? **Ranked species mean acute values for sulfate in compiled database for freshwater organisms (Wang et al. 2015), with the addition of mayfly data (Soucek and Dickinson 2015)**



Species mean acute value (SMAV) = Geometric mean of LC50/EC50 values for a species.

USGS

Freshwater mussel toxicity data used in 2013 updated WQC for ammonia to reflect the mussel sensitivity



"The four most acutely sensitive genera are all freshwater bivalve mussels…. are now among the most influential in the 2013 acute criterion dataset".

"The four most (chronically) sensitive species are predominantly mollusks".

USGS

Objectives of ongoing mussel studies

- Evaluate the sensitivity among different families and tribes of freshwater mussels?
- Determine the sensitivity to chemicals with different modes of action?
- Determine the utility of measuring growth endpoints in long-term exposures:
  - Optimize feeding conditions to reduce the variability of growth between tests
  - Compare chronic toxicity in 4- and 12-week exposures

Evaluation of the sensitivity of mussels among two families and four tribes to ten chemicals with different toxic modes of action (Wang et al. in prep.)

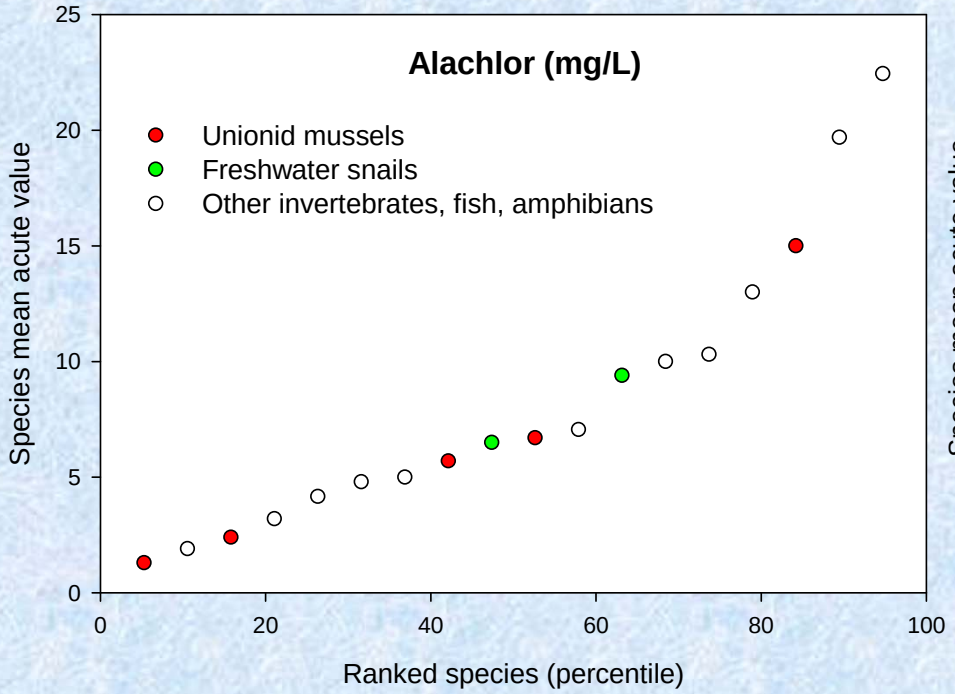
Test species
Mussels (about 1-week-old juveniles):
Family Unionidae
Amblemini tribe, *Amblema plicata*
Anodontini tribe, *Utterbackia imbecillis* and *Lasmigona complanata*
Lampsilini tribe, *Lampsilis siliquoidea*
Quadrulini tribe, *Megalonaias nervosa*
Family Margaritiferidae, *Margaritifera falcata*
Snails (about 1-week old):
Family Physidae, *Physa gyrina*
Family Lymnaeidae, *Lymnaea stagnalis*
Commonly tested species:
Cladoceran, *Ceriodaphnia dubia* (<24-h old)
Cladoceran, *Daphnia magna* (<24-h old)

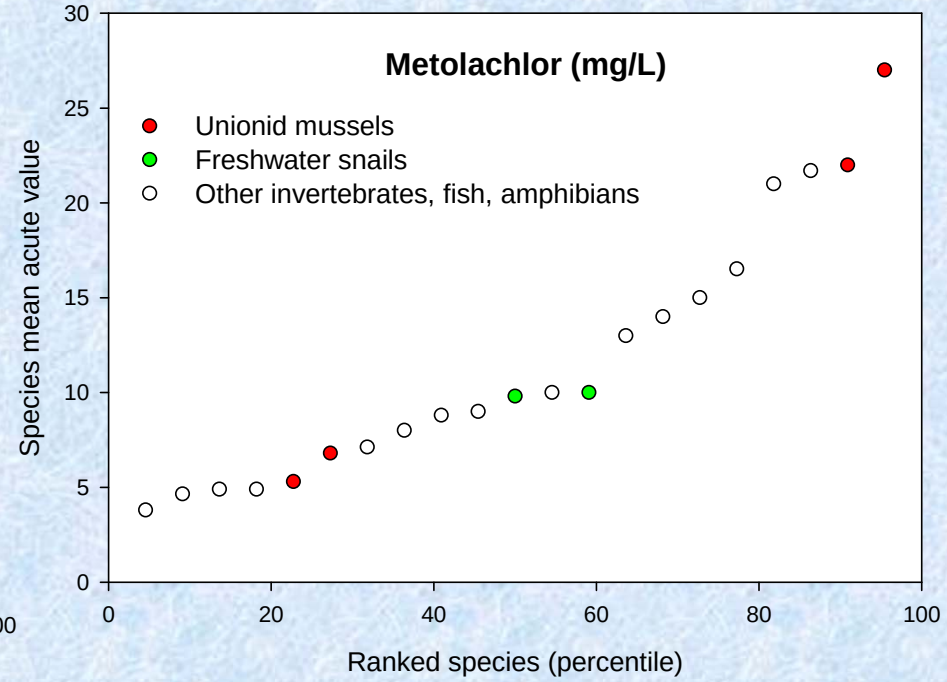
Toxicant	Chemical tested	Mode of action
Alachlor	Alachlor	Narcosis
Metolachlor	Metolachlor	Narcosis
Ammonia	Ammonium chloride	Narcosis
Potassium	Potassium chloride	Respiratory toxicity
Chloride	Sodium chloride	Respiratory toxicity
Sulfate	Sodium sulfate	Uncertain
Chromium (VI)	Chromium (VI) oxide	Metallic stress
Copper	Copper sulfate	Metallic stress
Nickel	Nickel chloride	Metallic stress
Zinc	Zinc chloride	Metallic stress

Newly transformed juvenile mussels (a few days after leaving a host fish)

USGS

Ranked species mean acute values in compiled database for freshwater organisms*, with the addition of juvenile mussel and snail data

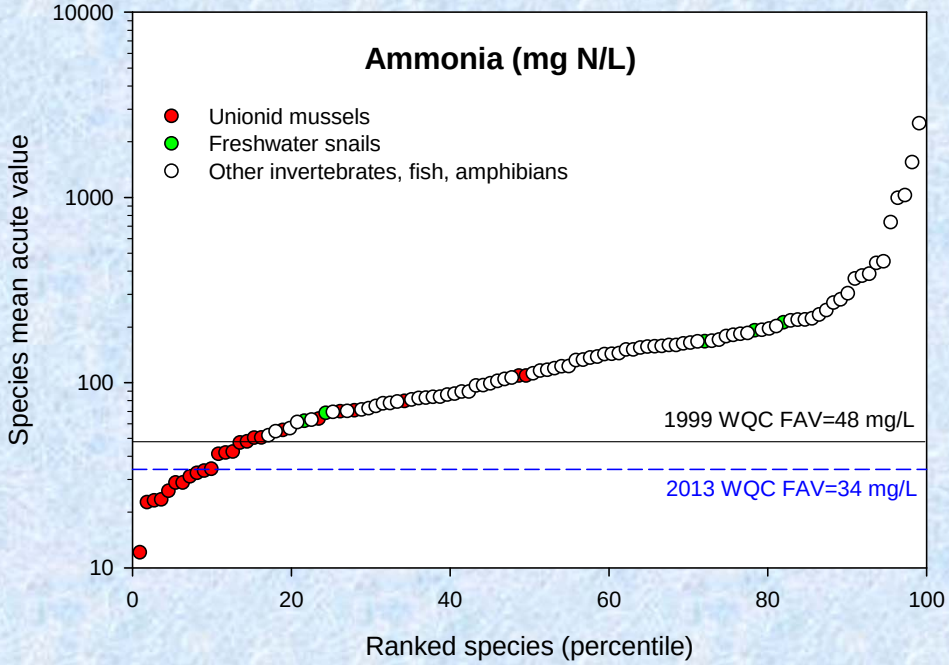


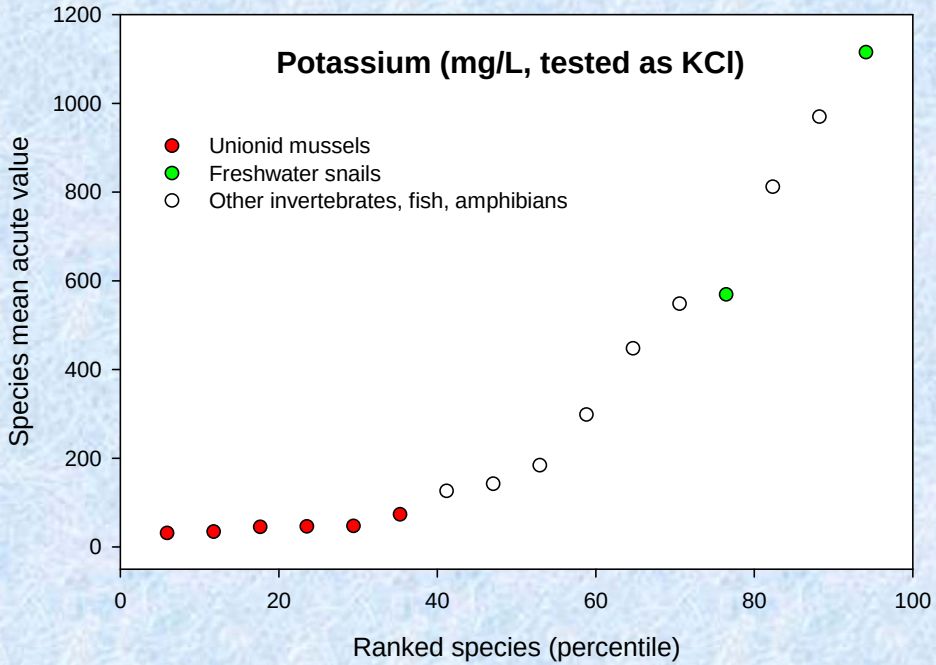


* USEPA Interspecies Correlation Estimation database for alachlor and metolachlor (Raimondo et al. 2010)

USGS

Ranked species mean acute values in compiled database for freshwater organisms*, with the addition of juvenile mussel and snail data

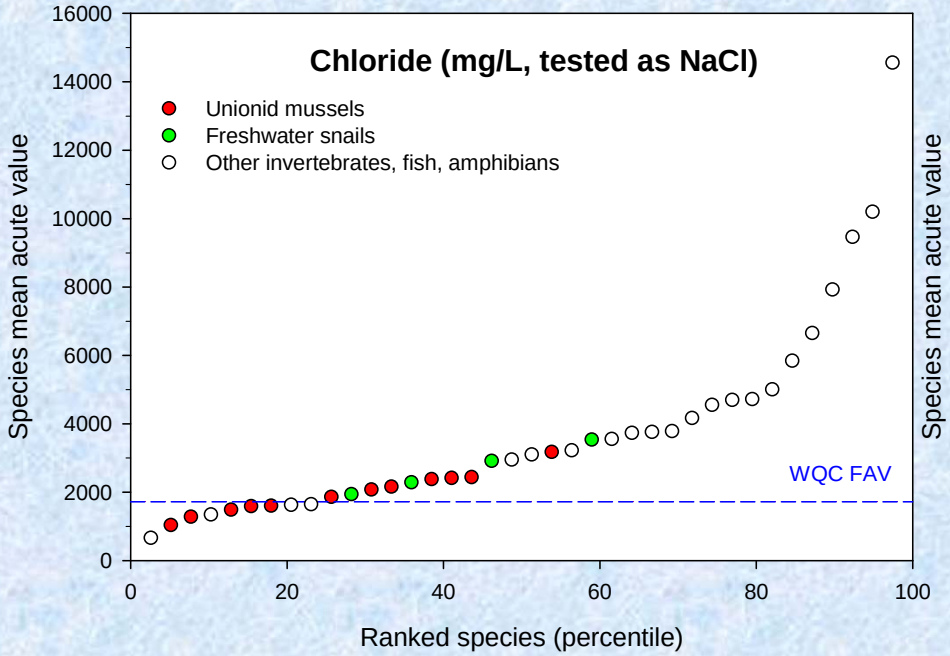


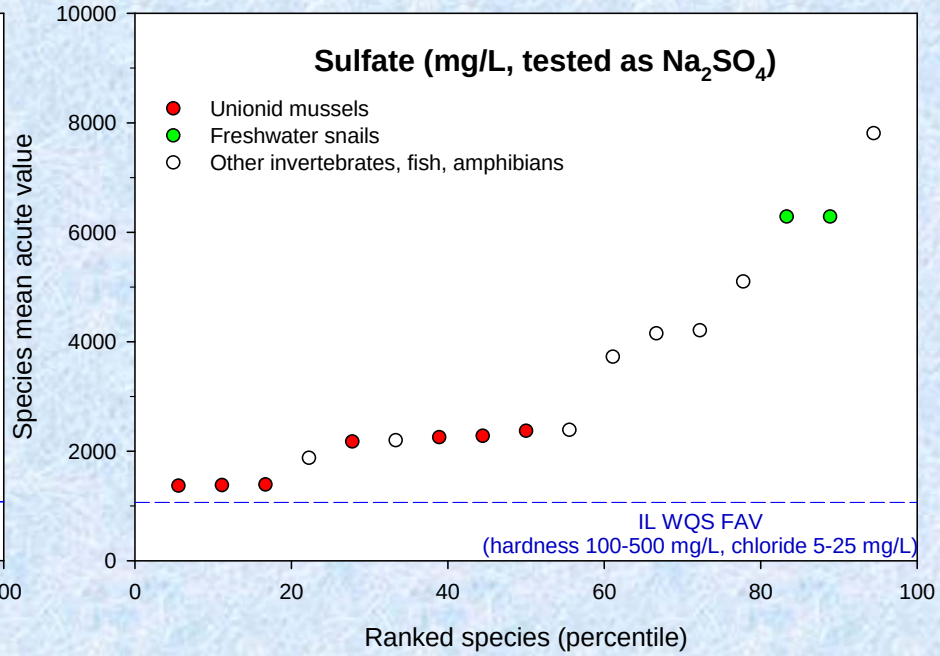


* USEPA 2013 WQC database for ammonia (adjusted to pH 7 and 20°C); USEPA Interspecies Correlation Estimation database for potassium (Raimondo et al. 2010)

USGS

Ranked species mean acute values in compiled database for freshwater organisms*, with the addition of juvenile mussel and snail data

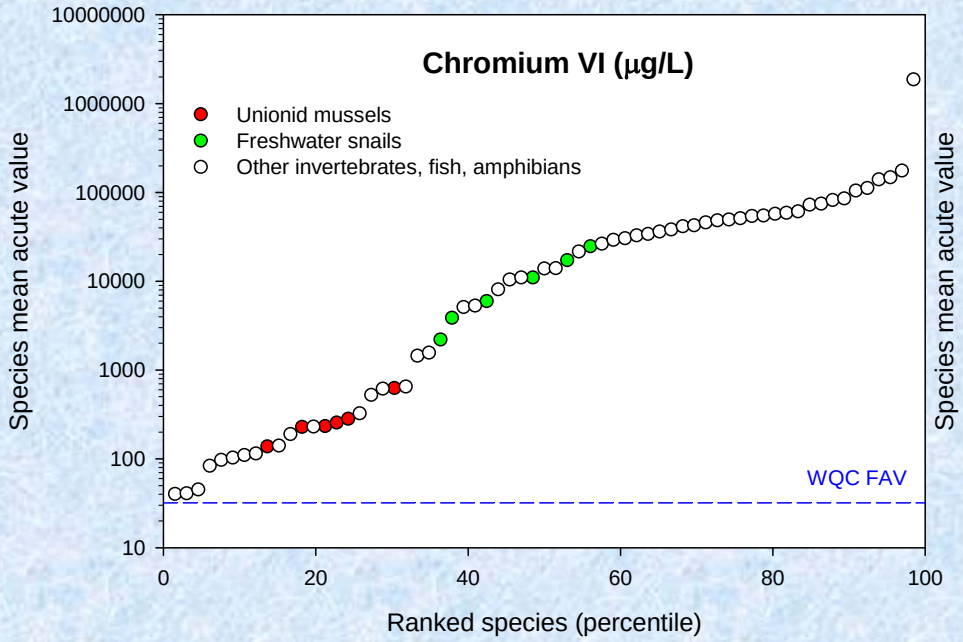


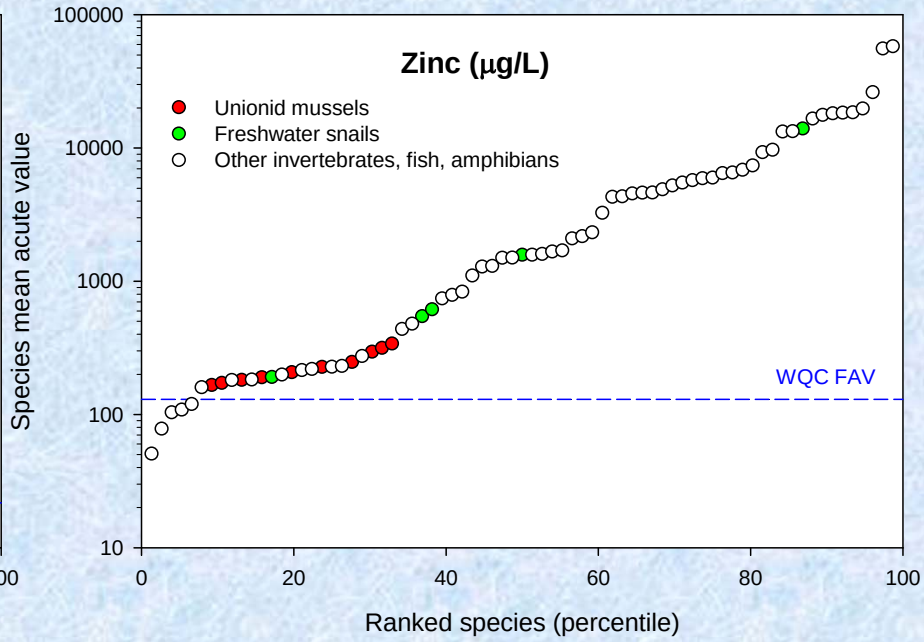


* Iowa State 2009 WQS database for chloride (hardness 80-180 mg/L, sulfate <200 mg/L); Illinois State 2008 WQS database for sulfate (hardness 80-120 mg/L, chloride <25 mg/L; Wang et al. 2015)

USGS

Ranked species mean acute values in compiled database for freshwater organisms*, with the addition of juvenile mussel and snail data

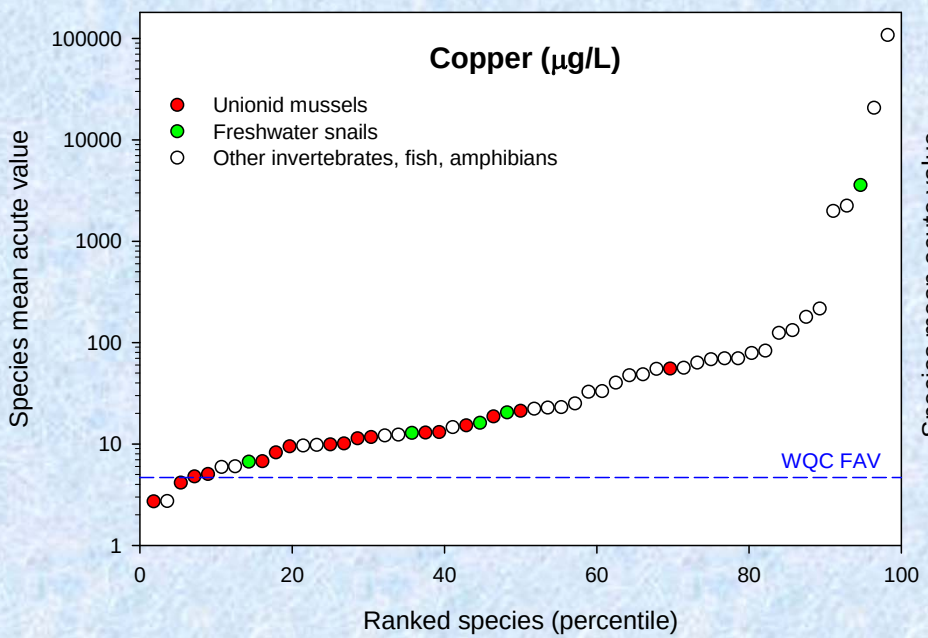


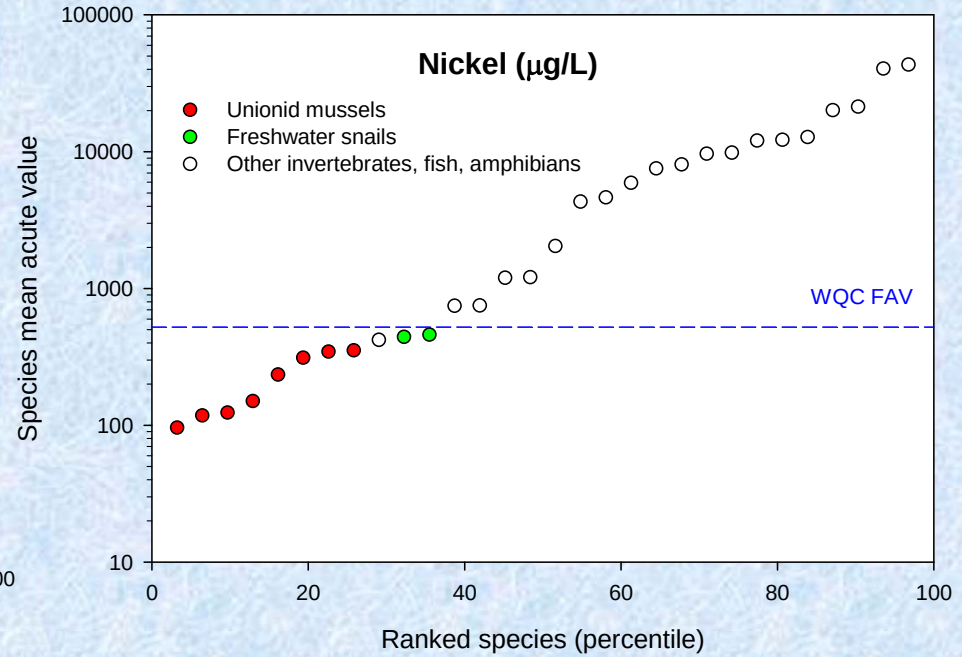


* USEPA Interspecies Correlation Estimation database for Chromium VI (Raimondo et al. 2010); zinc database (normalized to hardness 50 mg/L; DeForest and Van Genderen 2012)

USGS

Ranked species mean acute values in compiled database for freshwater organisms*, with the addition of juvenile mussel and snail data

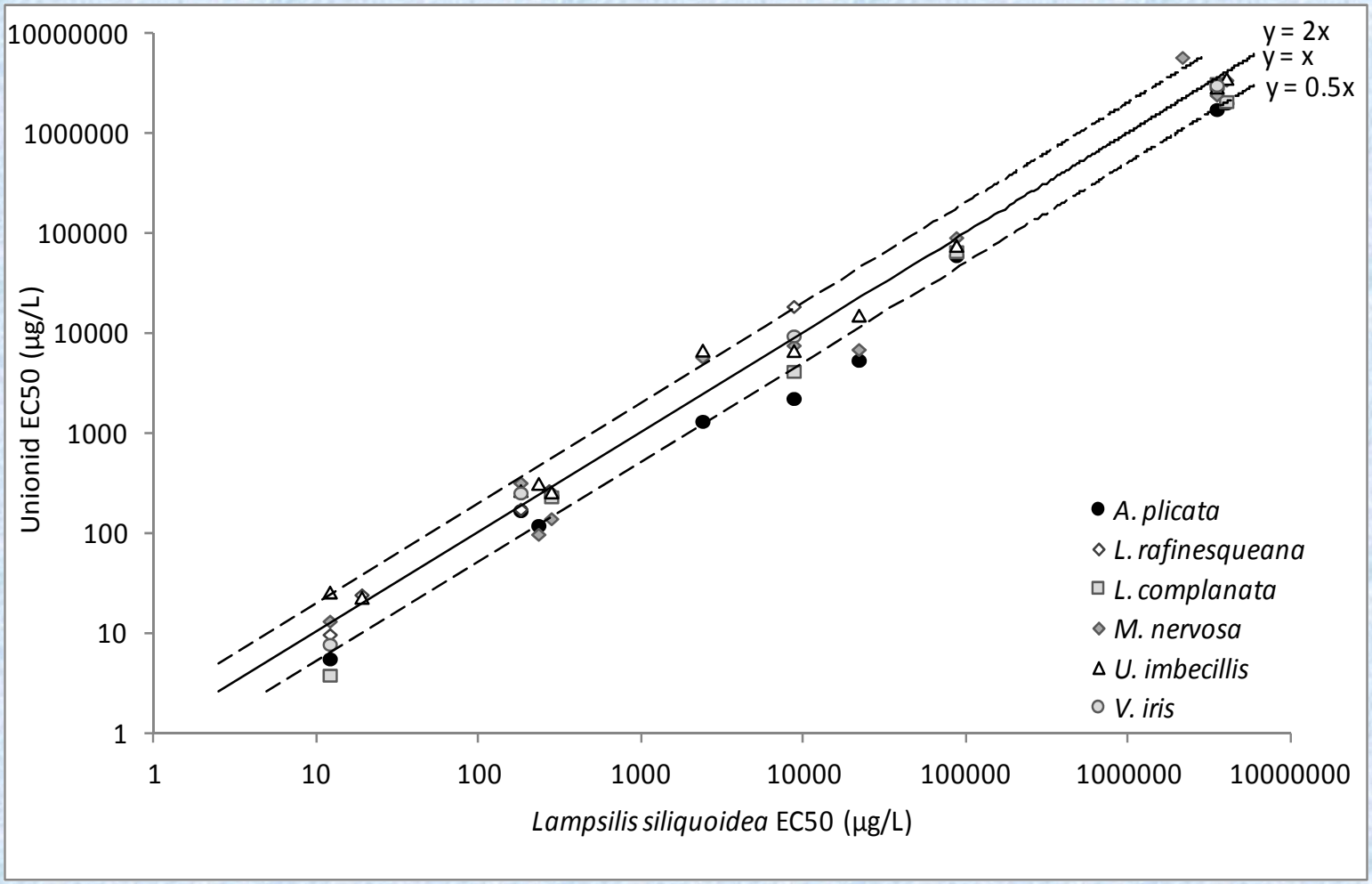




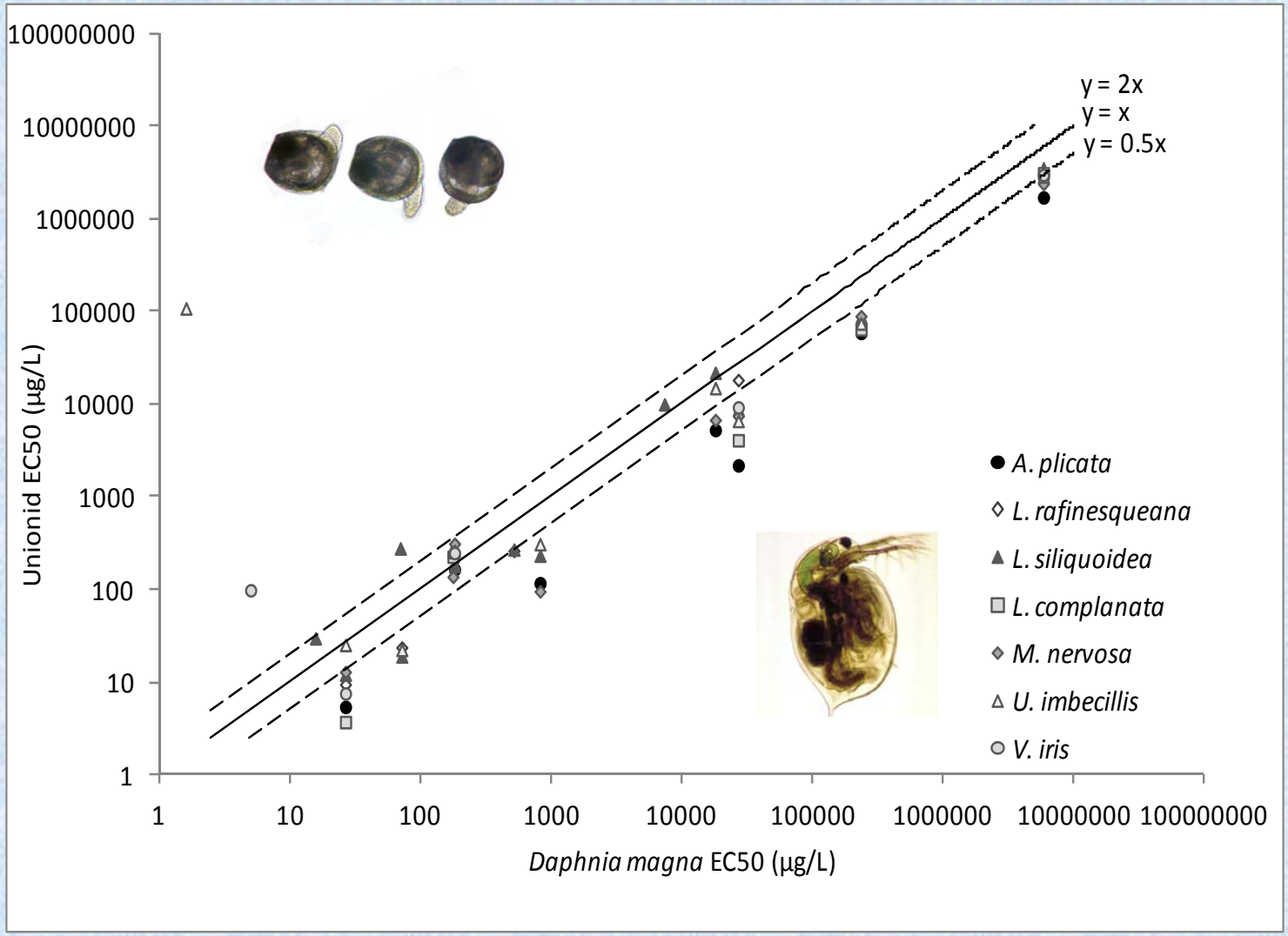
*USEPA 2007 BLM-based WQC database for copper; USEPA Interspecies Correlation Estimation database for nickel (normalized to hardness 50 mg/L; Raimondo et al. 2010)

USGS

Is a mussel a mussel? **Comparison of juveniles of a commonly tested mussel (fatmucket, *L. siliquoidea*) and other six mussel species in acute exposures to 10 chemicals (Raimondo et al. 2015)**

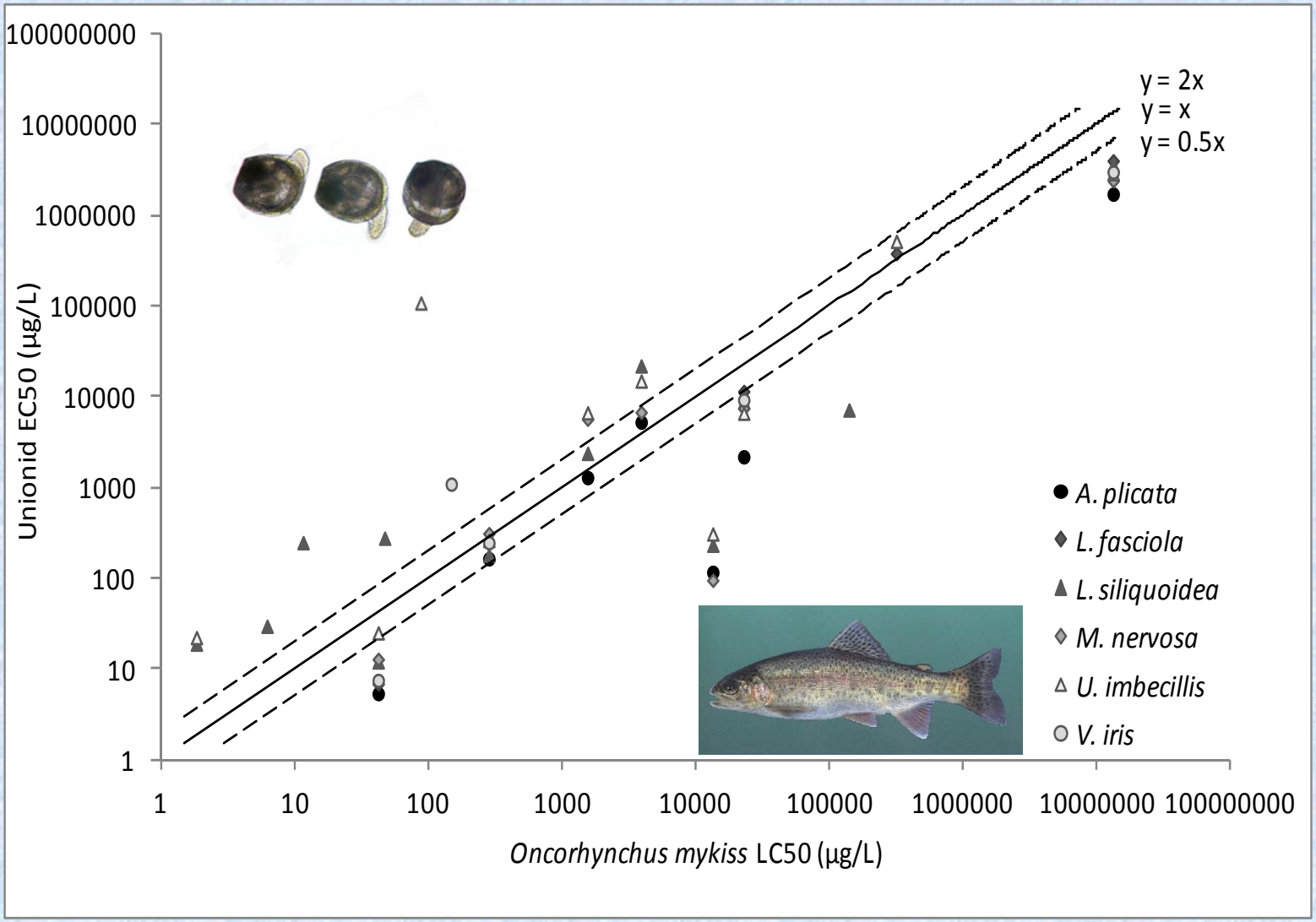


Is a mussel a crustacean? **Comparison of a commonly tested cladoceran (*Daphnia magna*) to juveniles of seven mussel species in acute exposures to 10 chemicals (Raimondo et al. 2015)**

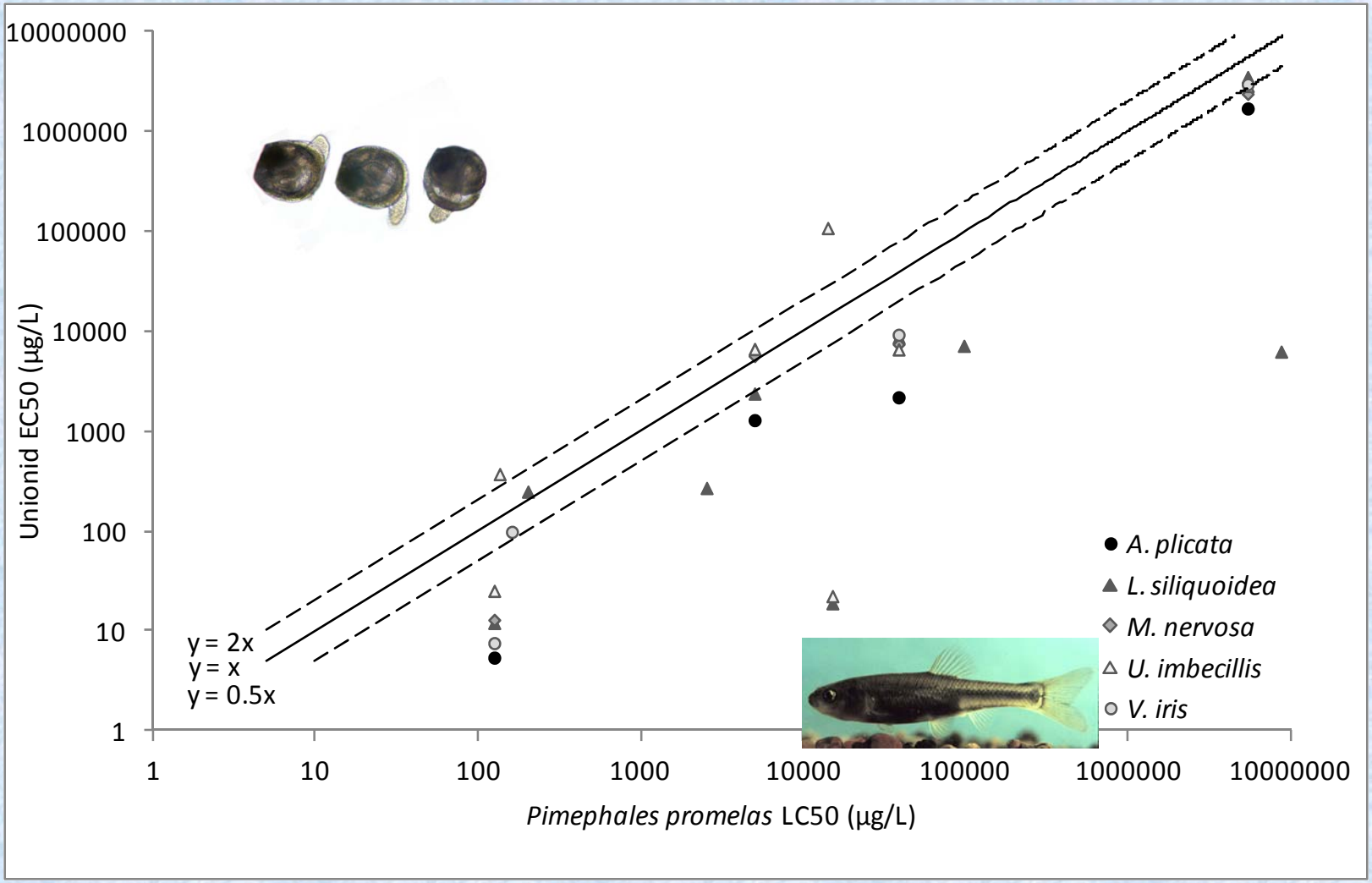


USGS

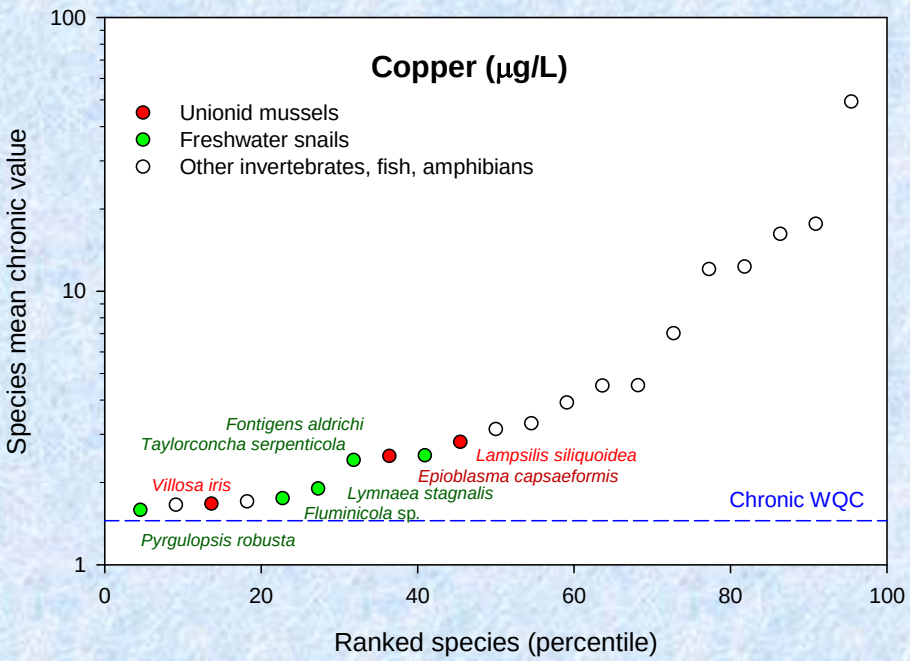
Is a mussel a fish? **Comparison of rainbow trout to juveniles of different six mussel species in acute exposures to 10 chemicals (Raimondo et al. 2015)**

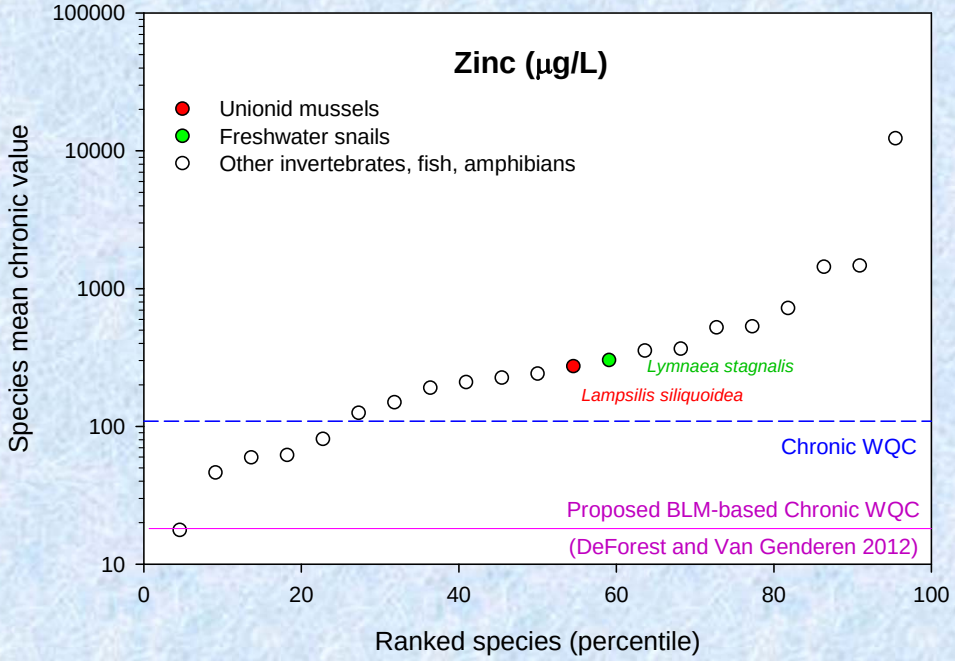


Is a mussel a fish? **Comparison of fathead minnow to juveniles of different mussel species in acute exposures to 10 chemicals (Raimondo et al. 2015)**



Examples of chronic sensitivity of mollusks: Ranked species mean chronic values in compiled database for freshwater organisms*, with the addition of mussel and snail data (Wang et al. 2010, 2014)



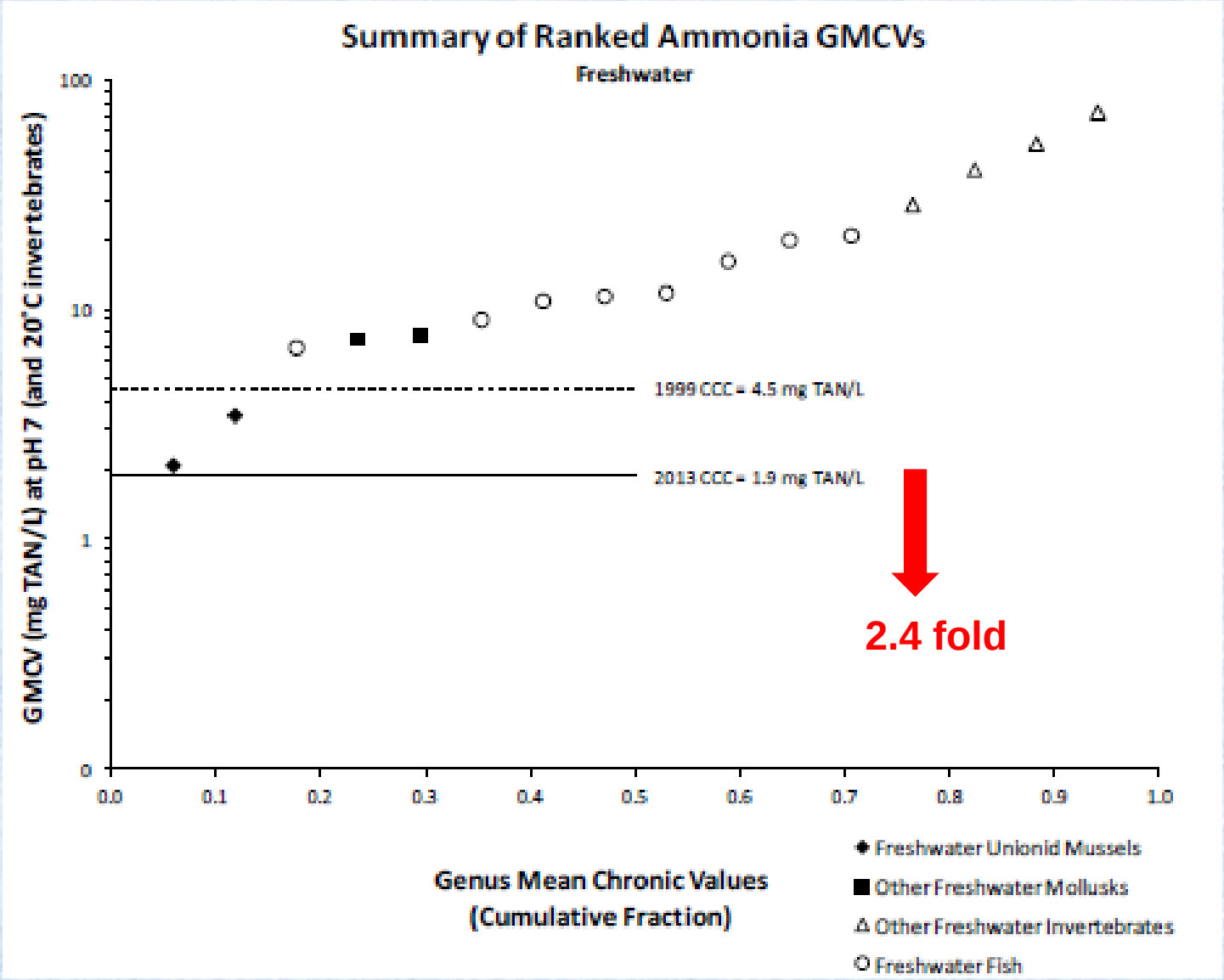


* BLM-normalized copper database (Chris Mebane of USGS, Boise, ID); BLM-normalized zinc database (DeForest and Van Genderen 2012)

Species mean chronic value = Geometric mean of LC20/EC20 values for a species

USGS

USEPA 2013 chronic water quality criterion: Ranked freshwater genus mean chronic values (GMCVs) with Criterion Continuous Concentration (CCC)



Summary of mussel sensitivity based on ranks in species sensitivity distributions and/or effect concentrations relative to FAVs or FCVs

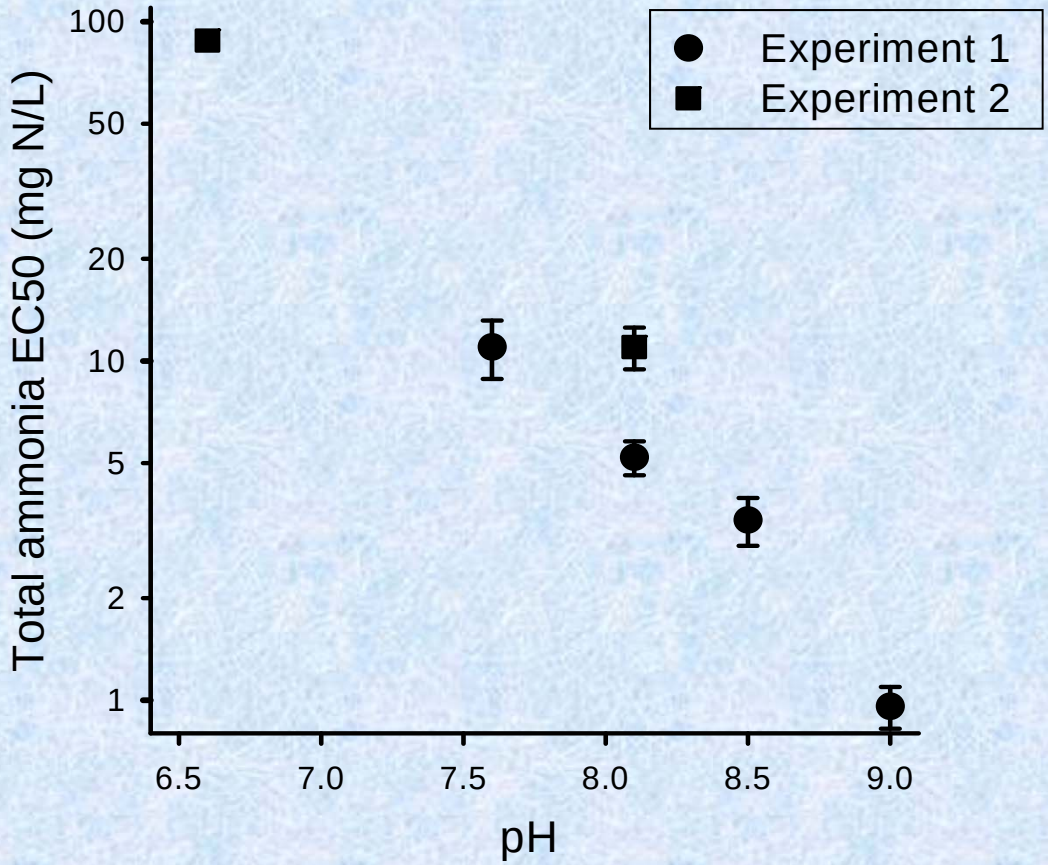
Chemical	Mussel sensitive		Snail sensitive	
	Acute	Chronic	Acute	Chronic
Alachlor[a]	Yes	ND[b]	No	ND
Metolachlor[a]	Yes	ND	No	ND
Ammonia	Yes	Yes	No	Yes
Potassium[a]	Yes	Yes[c]	No	ND
Chloride	Yes	Yes	No	ND
Sulfate[a]	Yes	Yes[c]	No	ND
Chromium VI	No	No[c]	No	ND
Copper	Yes	Yes	Yes	Yes
Nickel	Yes	Yes[c]	Yes	Yes[c]
Zinc	No	No	No	No
Lead	No[c]	No[c]	No[c]	Yes[c]
Cadmium	No[c]	No[c]	No[c]	No[c]

[a] No WQC for this chemical
[b] ND = not determined
[c] Data are not shown in this presentation (Wang et al. 2010, Besser et al. 2013, Wang et al. in prep.)

USGS

Can the bioavailability model in ammonia WQC predicts toxicity to mussels?

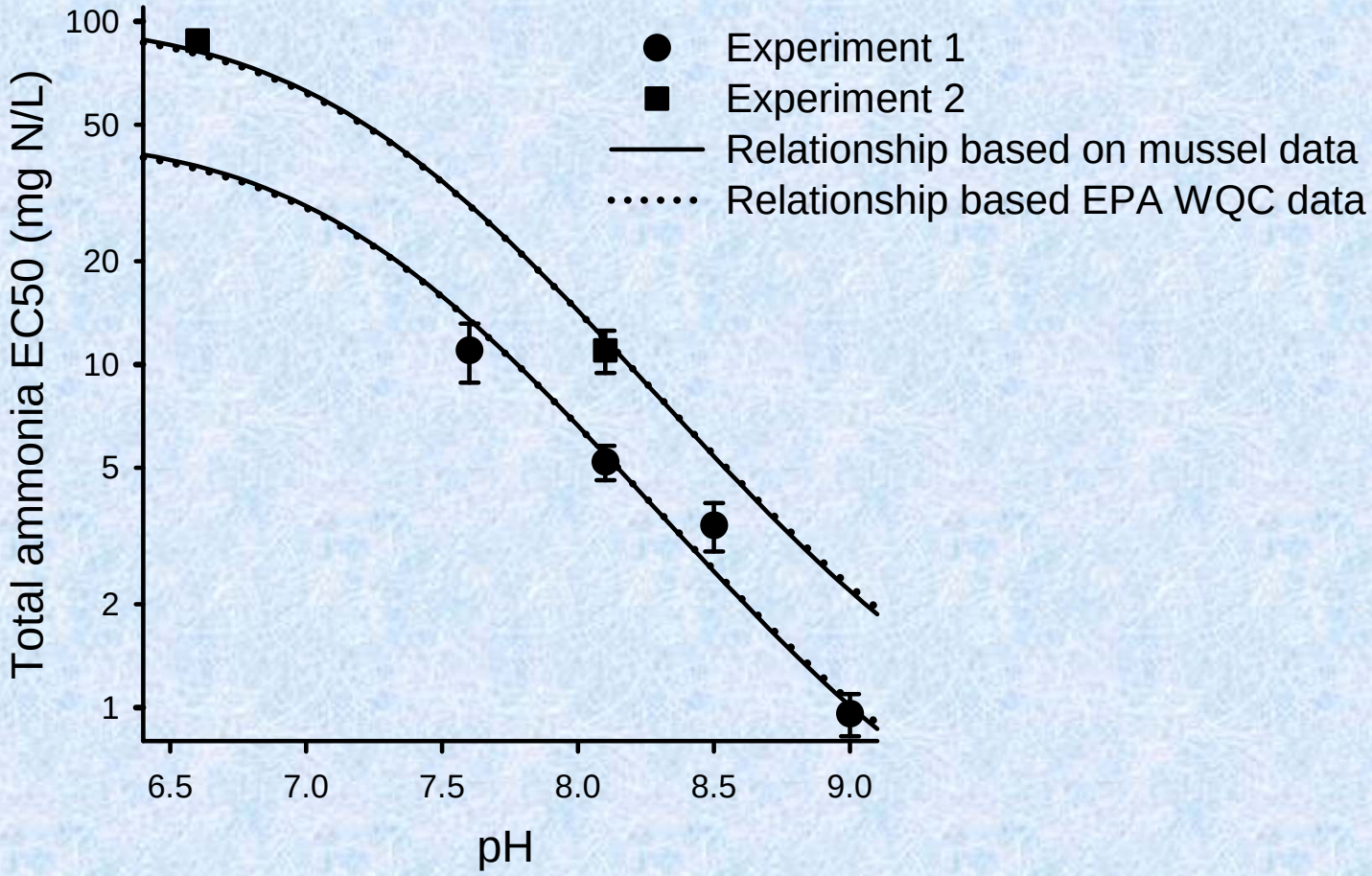
Acute 96-h ammonia EC50s for juvenile fatmucket (*L. siliquoidea*) at different pH levels (Wang et al. 2008)



Error bar: 95% confidence interval

USGS

Acute EC50 versus pH relationships for fatmucket data and for pooled data in USEPA WQC for ammonia, fitted to coincide with the same EC50s at pH 8.0 (Wang et al. 2008)

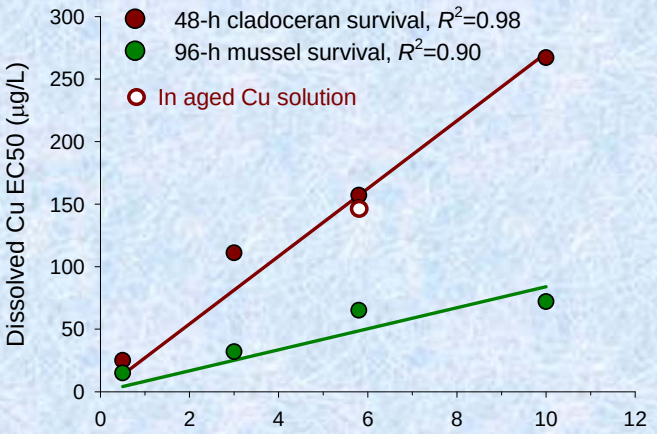


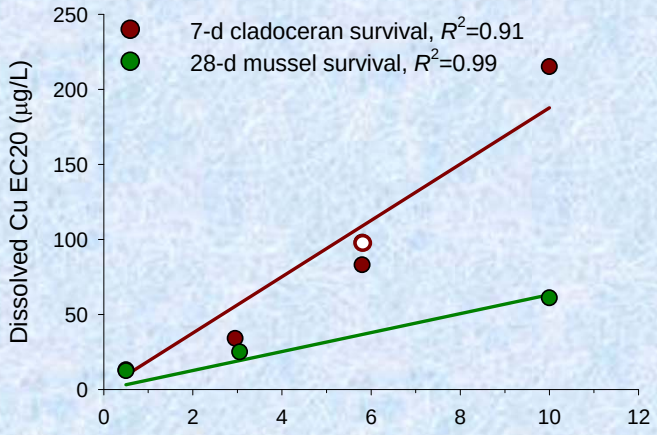
Error bar: 95% confidence interval

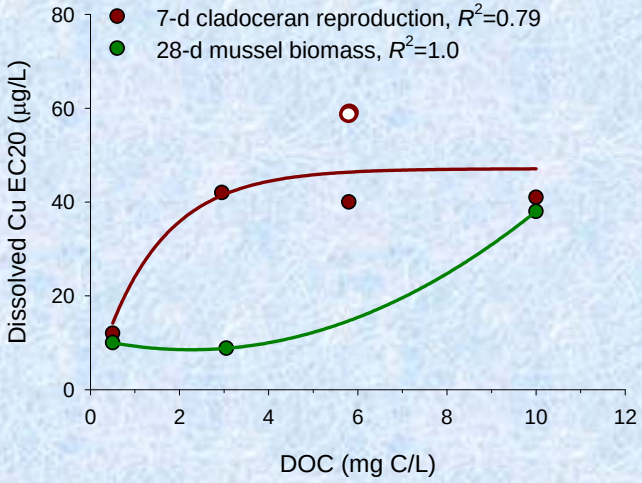
USGS

Can the BLM in copper WQC predicts toxicity to mussels?

Acute copper EC50, chronic EC20 for cladceran (*C. dubia*) and rainbow mussel (*Villosa iris*) at different concentrations of dissolved organic carbon (DOC) in a test water (hardness 100 mg/L; Wang et al. 2011)

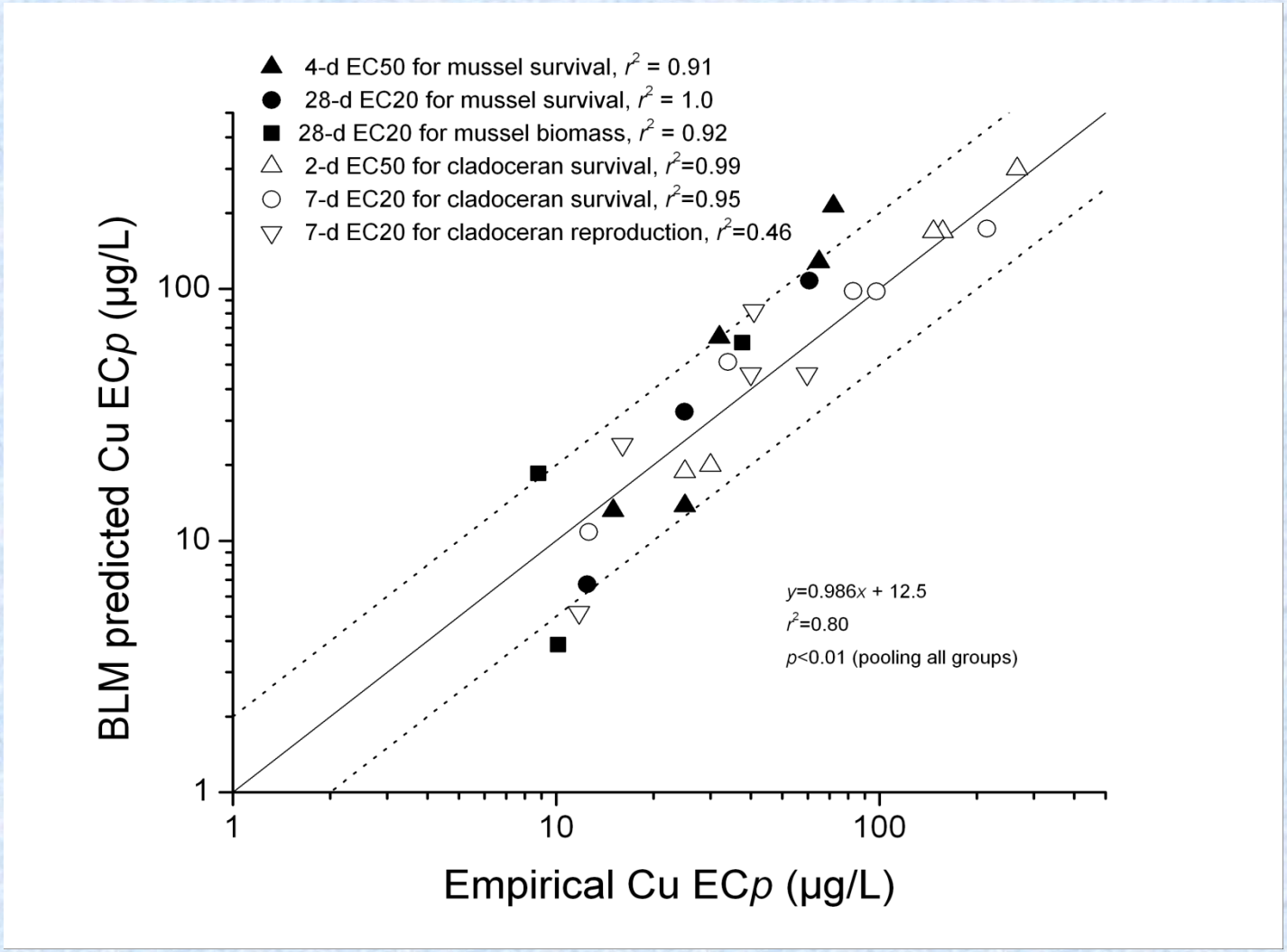






USGS

Observed- and BLM-predicted acute copper EC50 and chronic EC20 for the cladoceran (*C. dubia*) and rainbow mussel (*V. iris*; Wang et al. 2011)



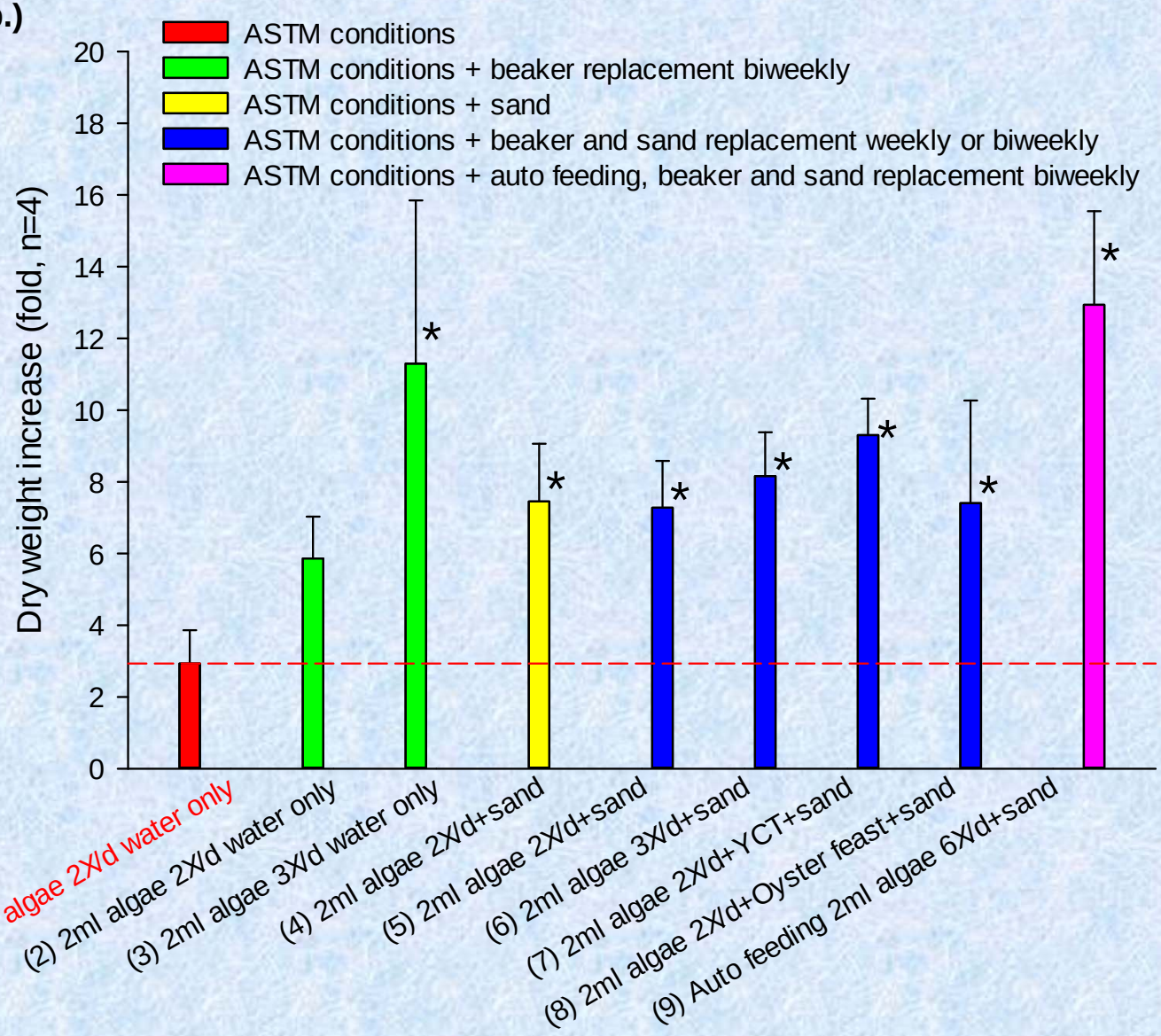
Line of perfect agreement

Upper dashed line indicates predicted ECp was 2X higher than observed ECp and vice versa for lower dashed line

USGS

Optimizing conditions to improve mussel growth in chronic water exposures: Dry weight increase relative to initial weight in 4-week study with a flow-through diluter starting with 2-month-old fatmucket (Kunz et al. in prep.)

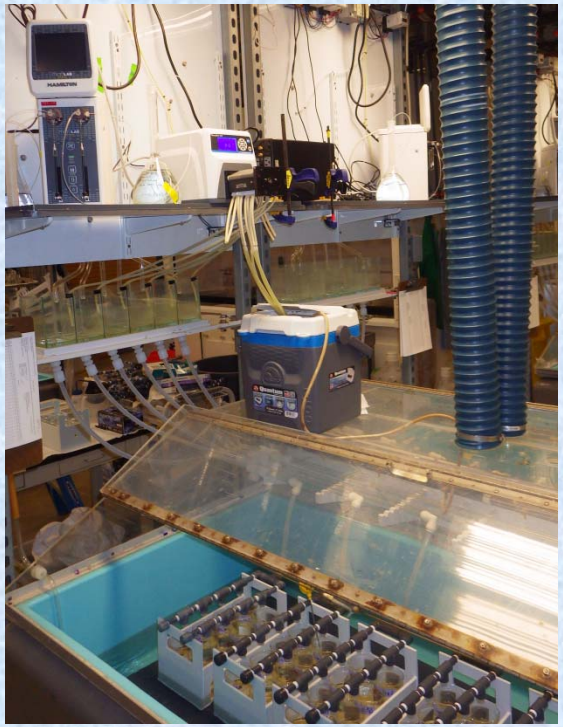
300-ml beaker containing 200-ml water and 5-ml sand



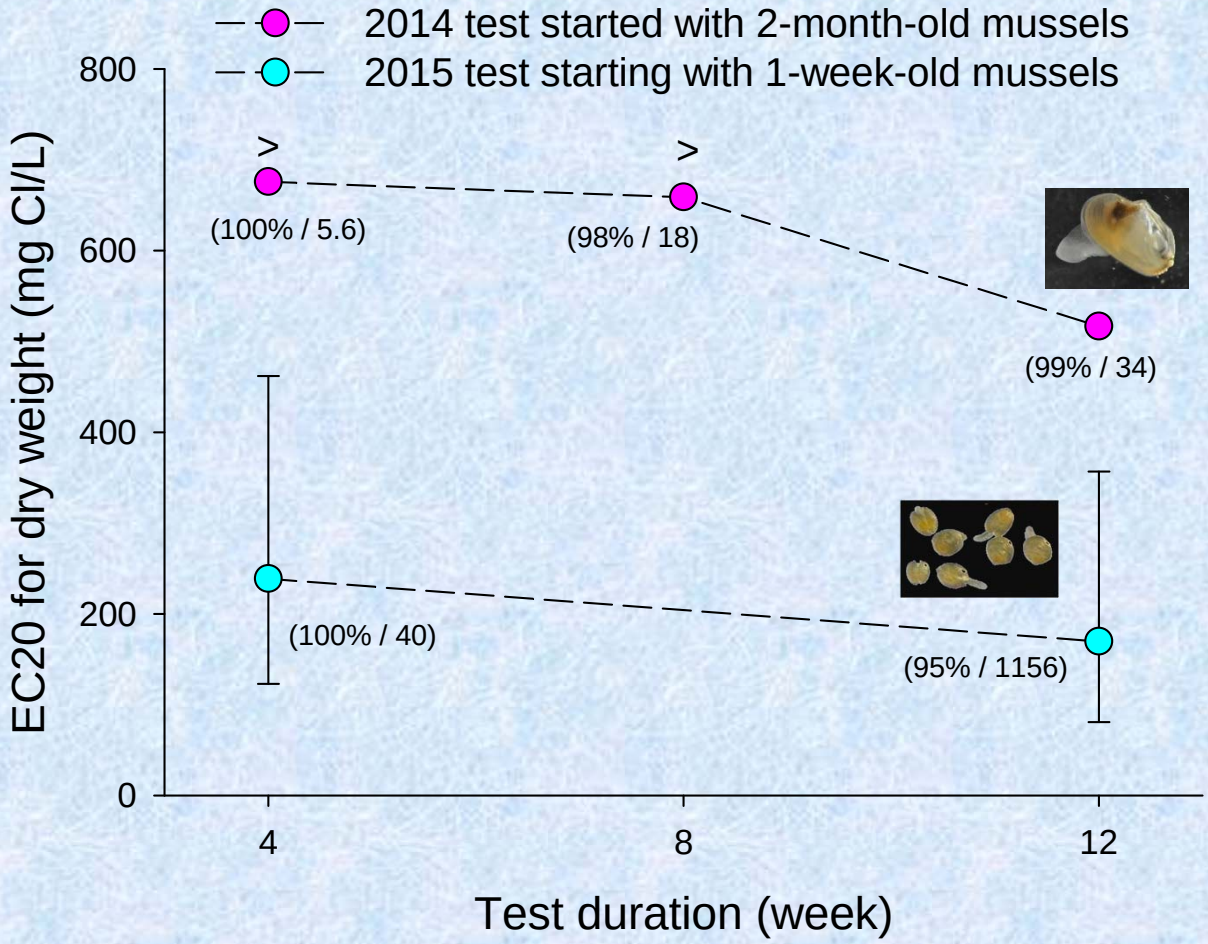
Error bar: standard deviation. *significant increase relative to the treatment under ASTM conditions (one-tailed Dunnett's test, $p<0.05$)

USGS

Influence of test duration and mussel life stages: Chronic EC20s in two 4- to 12-week NaCl exposures with juvenile fatmucket under refined test conditions with auto feeding. Control survival and weight fold increase in parenthesis (Wang et al. in prep.)



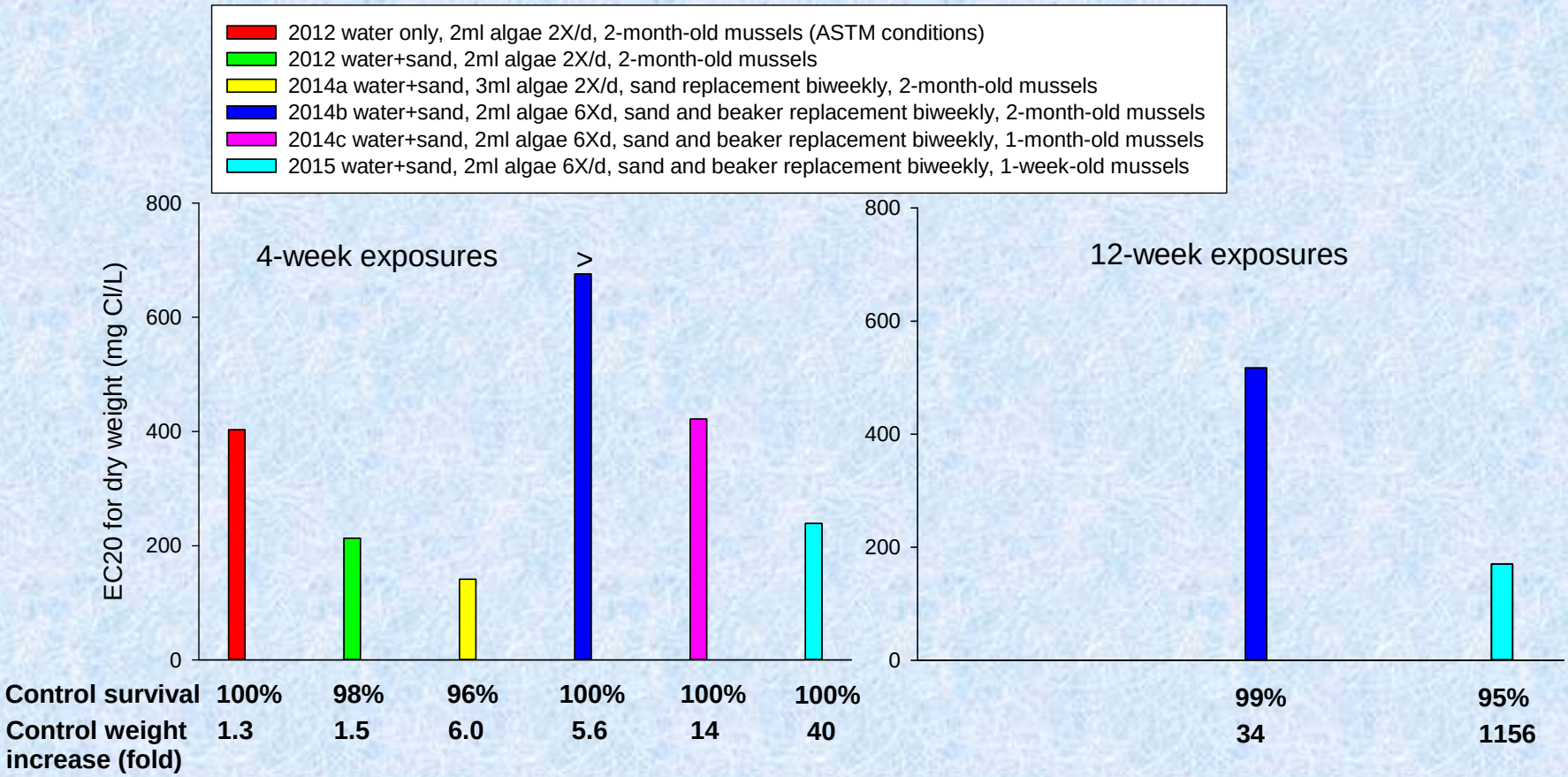
Intermittent flow-through proportional diluter with auto feeding of algal mixture



>: greater than. Error bar: 95% confidence limits

USGS

Chronic EC20s in 4- to 12-week NaCl exposures with juvenile fatmucket conducted before and after refining test conditions to improve growth (Wang et al. in prep.)



Recommendations for Minimum Data Requirement

- **Retain "sensitive" species**, even though some of them are not prevalent in some waters, to represent the sensitivity of many untested species (e.g., rainbow trout represents warm water fish)
- **Include nontraditional test species** (e.g., mayfly, sculpin, sturgeon) and associated nonstandard test methods to improve the protectiveness of WQC
- **Include native mussels** as a required family (the 9th family)
- **Use mussel growth data** from 4- to 12-week toxicity tests to derive chronic criterion