Sediment toxicity testing:

(1) Contaminants of emerging concern and
(2) Sensitivity of early life stages of freshwater mussels

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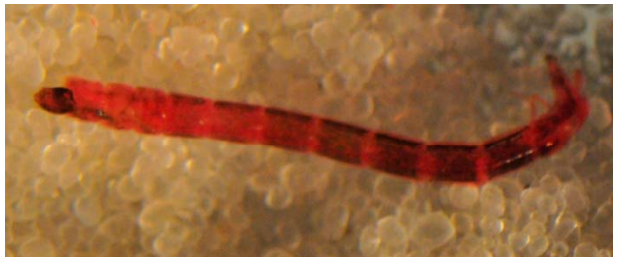
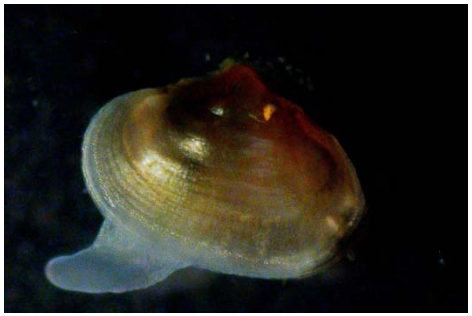
Department of the Interior
U. S. Geological Survey

Hyalella azteca; amphipod

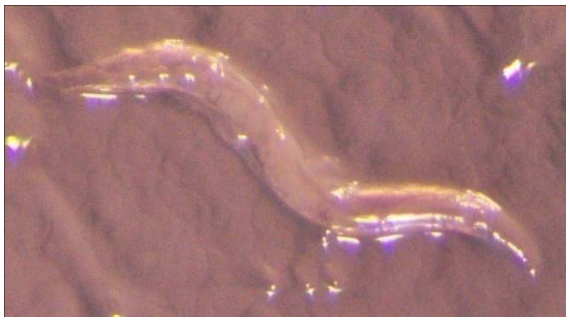
Gammarus pseudolimnaeus; amphipod



Chironomus riparius and *C. dilutus*; midge



Lampsilis siliquoidea; fatmucket



Caenorhabditis elegans; nematode

Lumbriculus variegatus and *Tubifex tubifex;* oligochaetes

Hexagenia spp.; mayfly

Overview

- Contaminants of emerging concern in sediment:
  - Pyrethroids and USGS NAWQA 2007 National Urban Stream Bed Sediment Pilot Study
  - Toxicity of nanomaterials:
    - Multi-wall carbon nanotubes (MWCNTs) spiked in sediment
    - Particles:10 to 25 nm wide x µm (electronics, fabrication)
- Sensitivity of mussels to contaminants:
  - Water toxicity testing:
    - Ammonia or metals
  - Whole-sediment toxicity testing:
    - Metal-contaminated mining sites in Missouri
    - Coal-impacted mining sites in Virginia and Tennessee

USGS

USGS NAWQA 2007 National Urban Stream Bed Sediment Pilot Study: 98 sediment samples from 7 study units

USGS

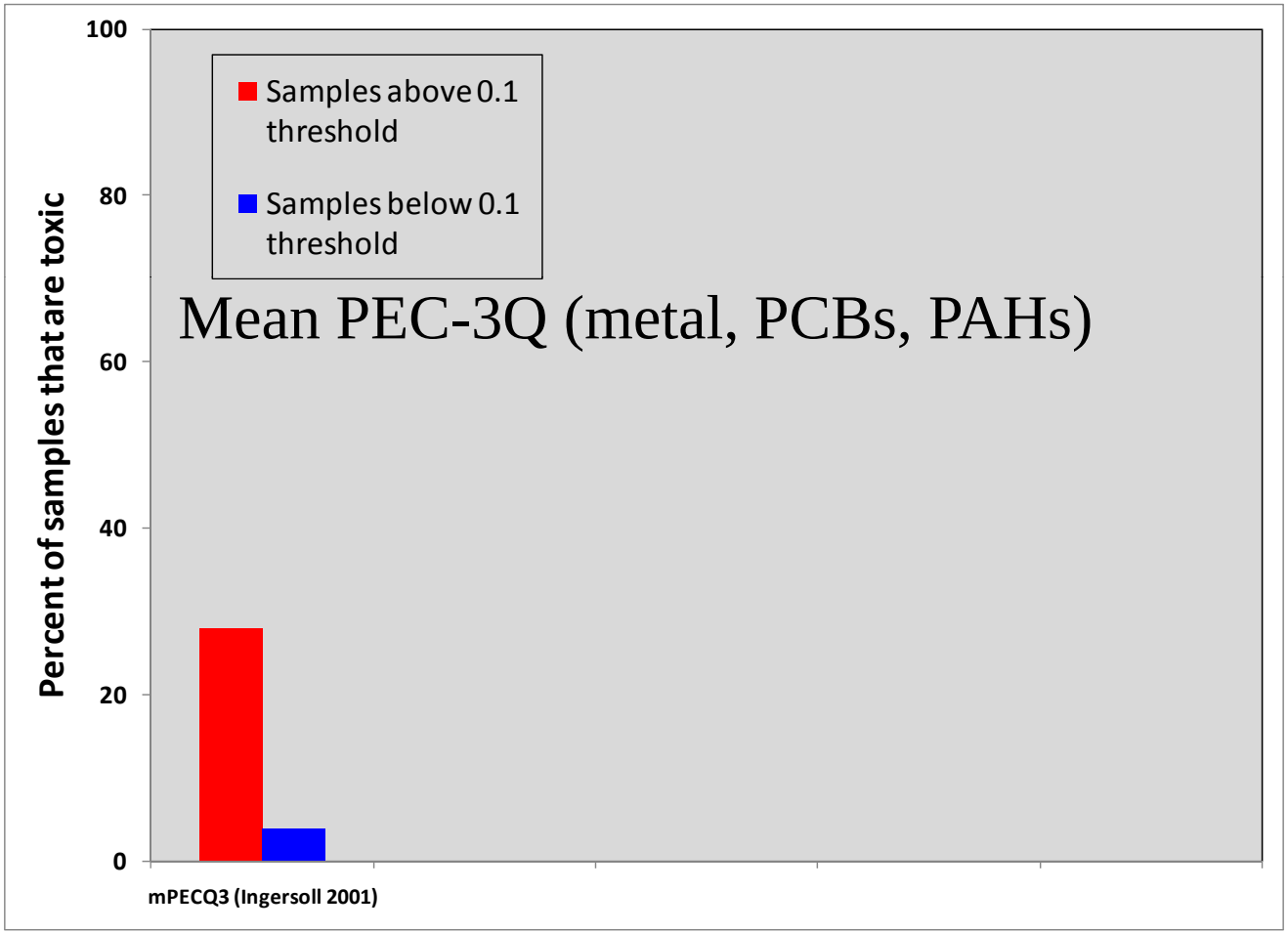
USGS

Percent samples toxic to amphipods (*H. azteca*; 28-d exposure) or midge (*C. dilutus*; 10-d exposure)

Study Unit	N	Amphipod Survival	Amphipod Weight	Amphipod Biomass	Amphipod All Endpoints	Midge Survival	Midge Weight	Midge Biomass	Midge All Endpoints	All Tests and Endpoints
Atlanta	13	38	0	0	38	0	0	8	8	38
Boston	14	14	14	14	21	0	29	36	36	43
Dallas	13	69	31	62	69	0	8	0	8	69
Denver	13	23	8	8	23	0	0	0	0	23
Milwaukee	12	33	8	17	33	0	17	17	17	33
Salt Lake City	12	33	17	25	33	17	17	17	33	50
Seattle	21	19	0	0	19	0	0	5	5	24
Total	98	32	10	16	33	2	9	11	14	39

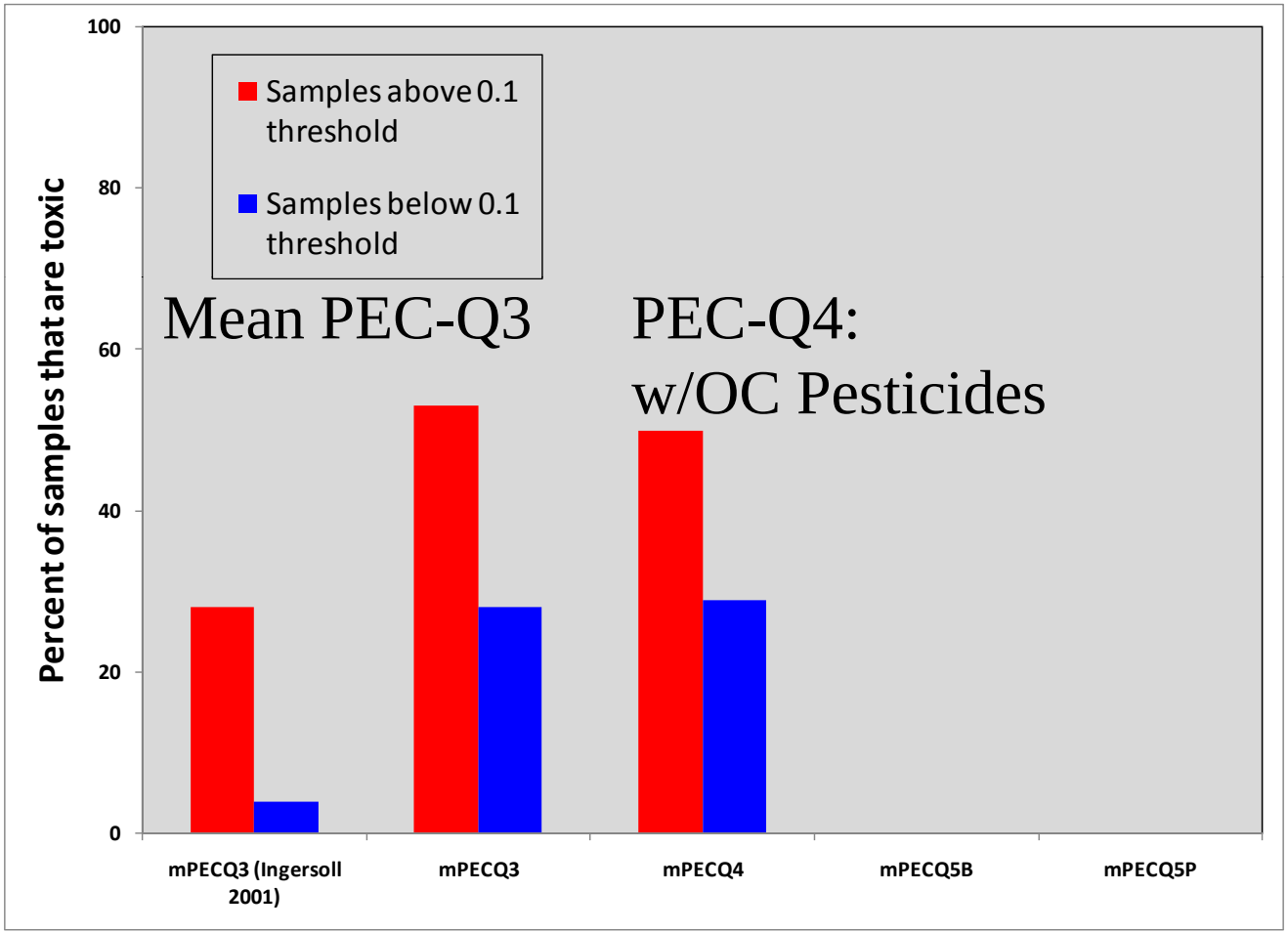
Kemble et al. (2010)

Threshold of toxicity at mean PEC-quotient <0.1 in 28-d tests with *H. azteca* (Ingersoll et al. 2001)



Kemble et al. (2010)

Percent samples toxic to *H. azteca* in the USGS NAWQA study (n=98)



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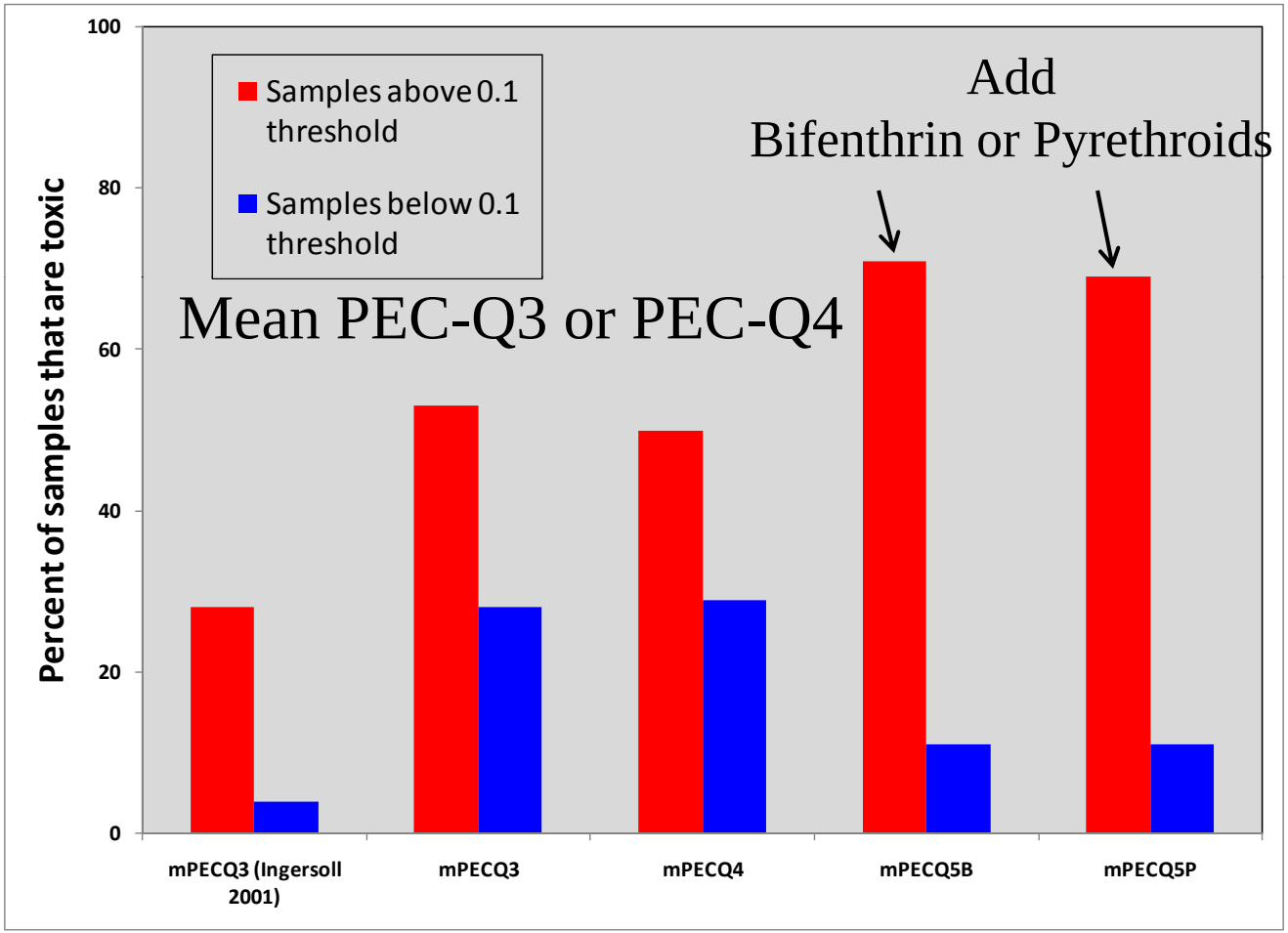
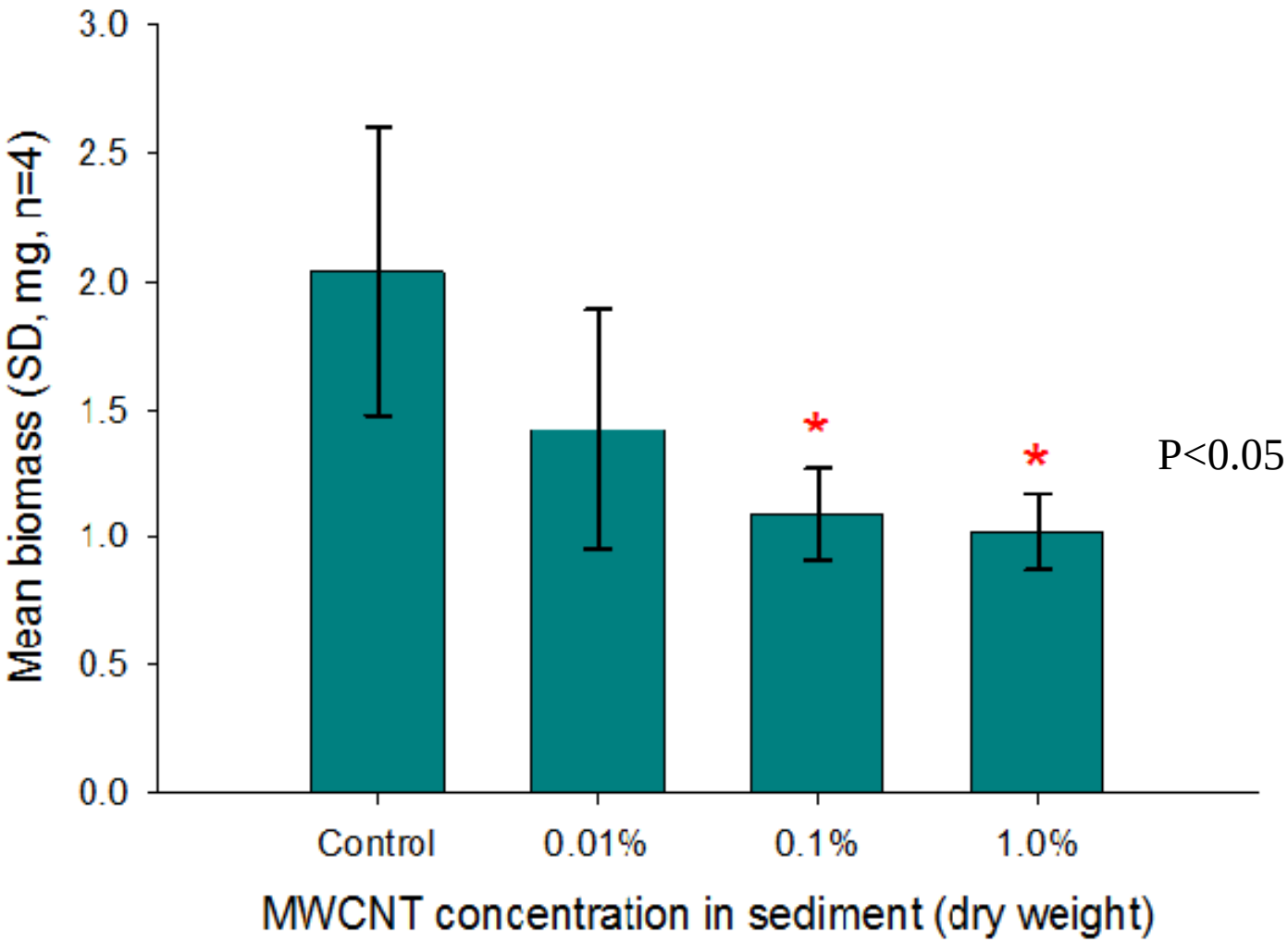


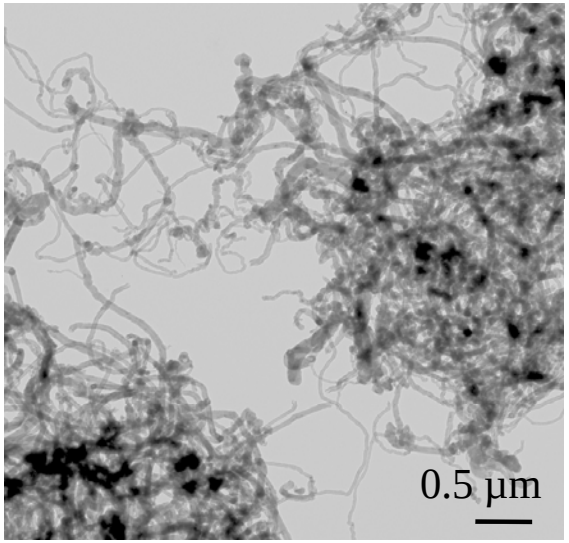
Kemble et al. (2010)

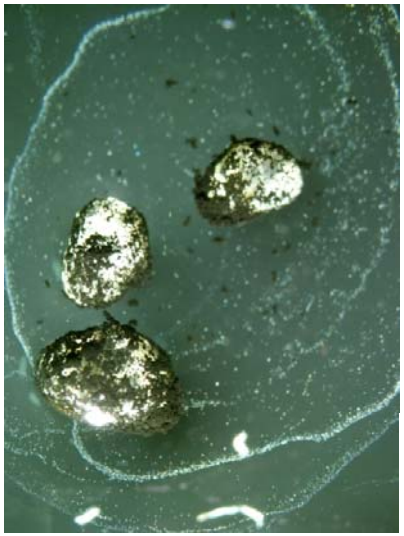
Toxicity of Multi-wall Carbon Nanotubes to *H. azteca* in 14-d sediment spiking exposures

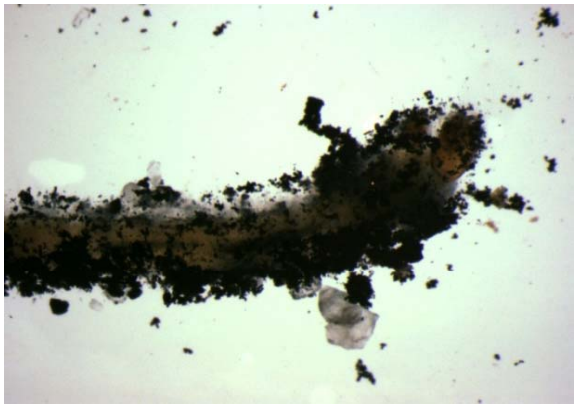


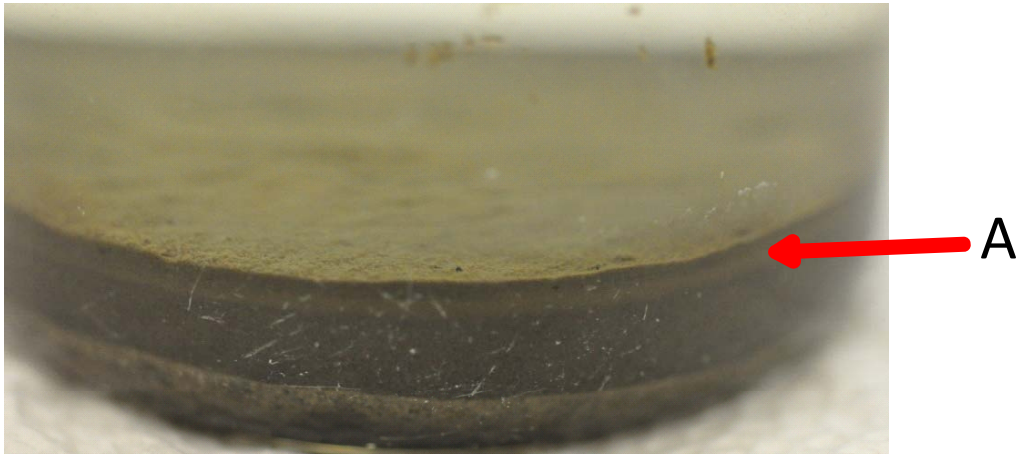
Mwangi et al. (2010)

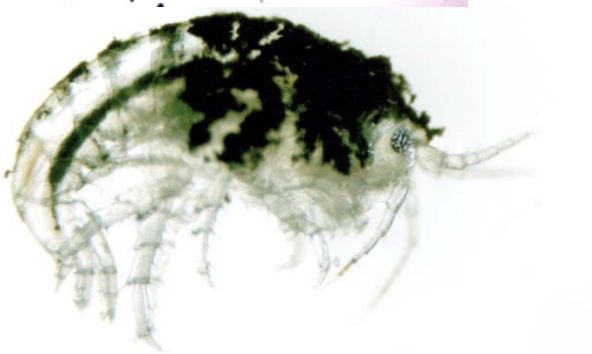
Behavior of nanomaterials





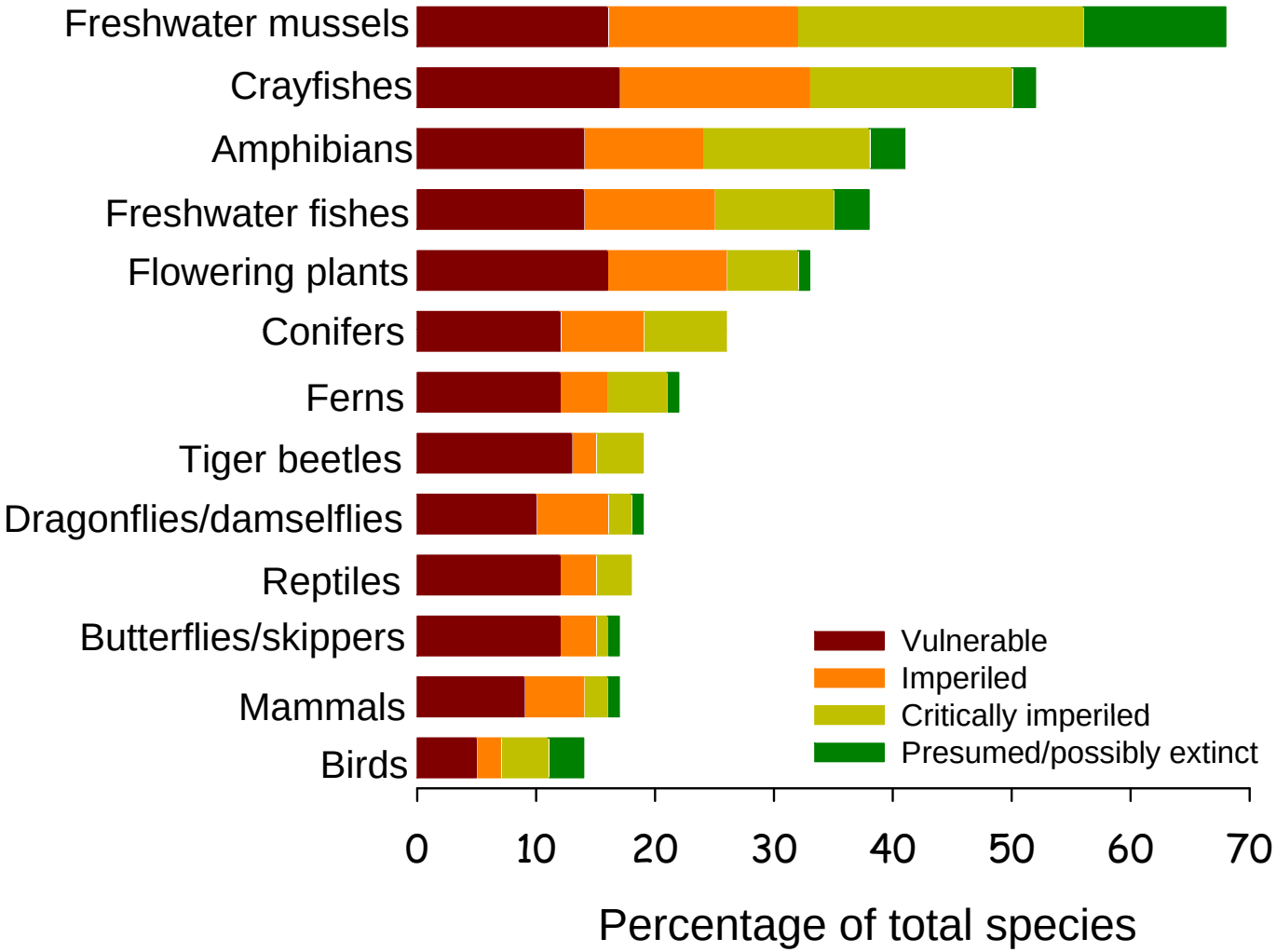






Mwangi et al. (2010)

Organisms listed as vulnerable, imperiled, or extinct in the United States



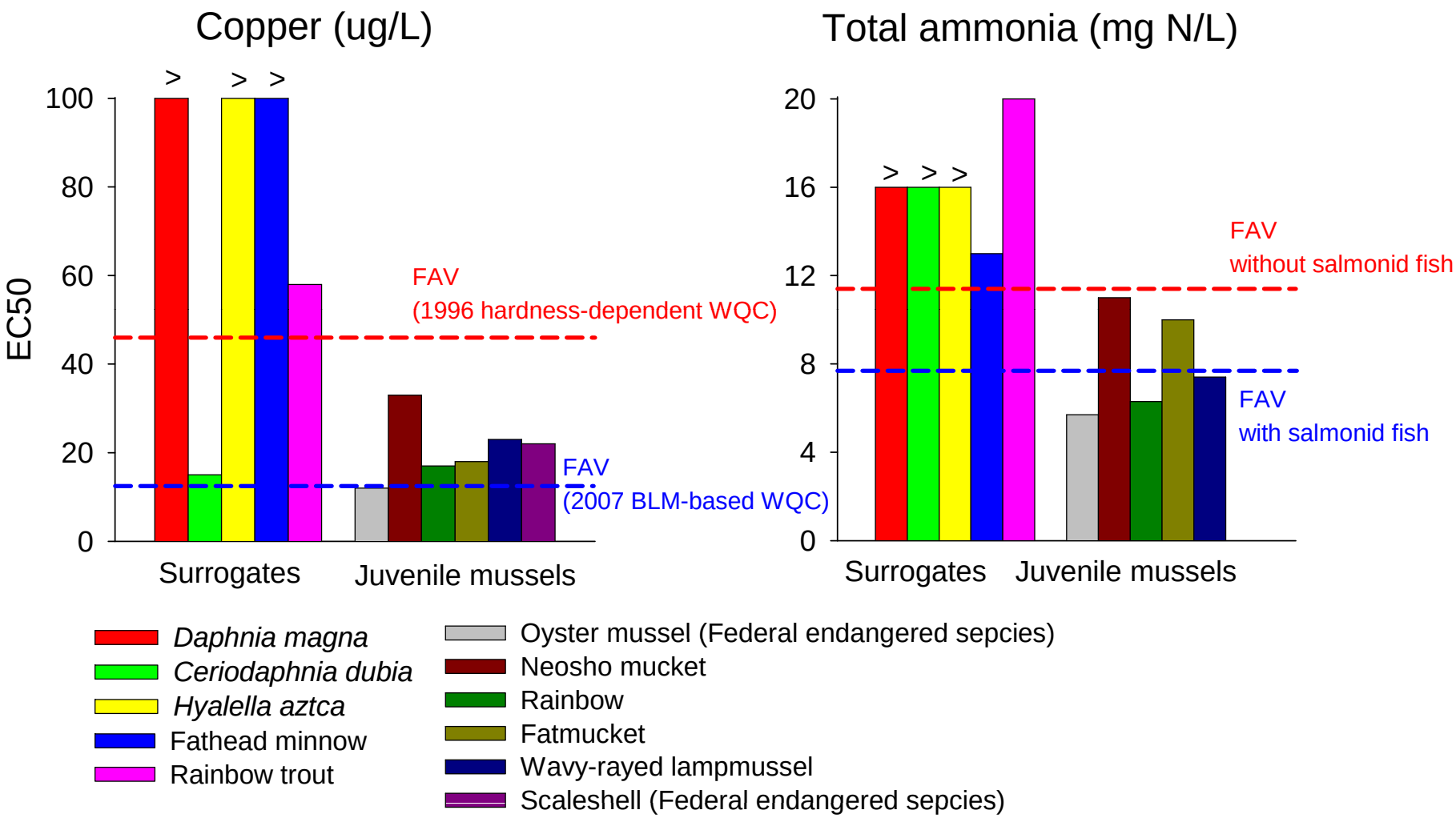
Stein et al. (2000)

Potential causes for the decline of mussels in North America

- Habitat alteration
- Introduction of exotic species
- Over-utilization
- Disease
- Predation
- Pollution

ASTM (2009)

96-h EC50s of copper or ammonia for newly transformed mussels, compared to 48- or 96-h EC50s for surrogate species

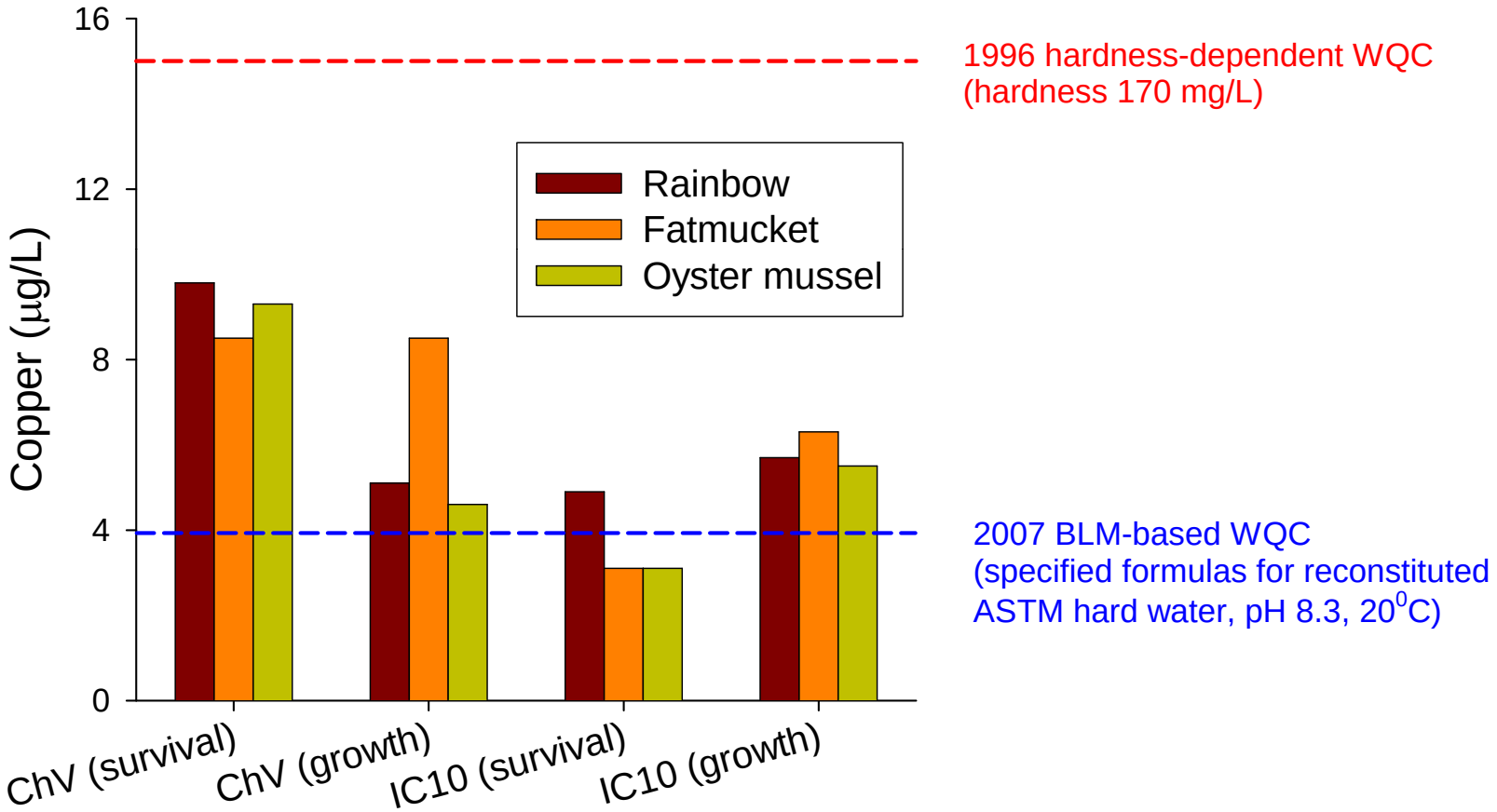


FAV: Final acute value for ASTM hard water (e.g., hardness 170 mg/L, pH 8.2)

USGS

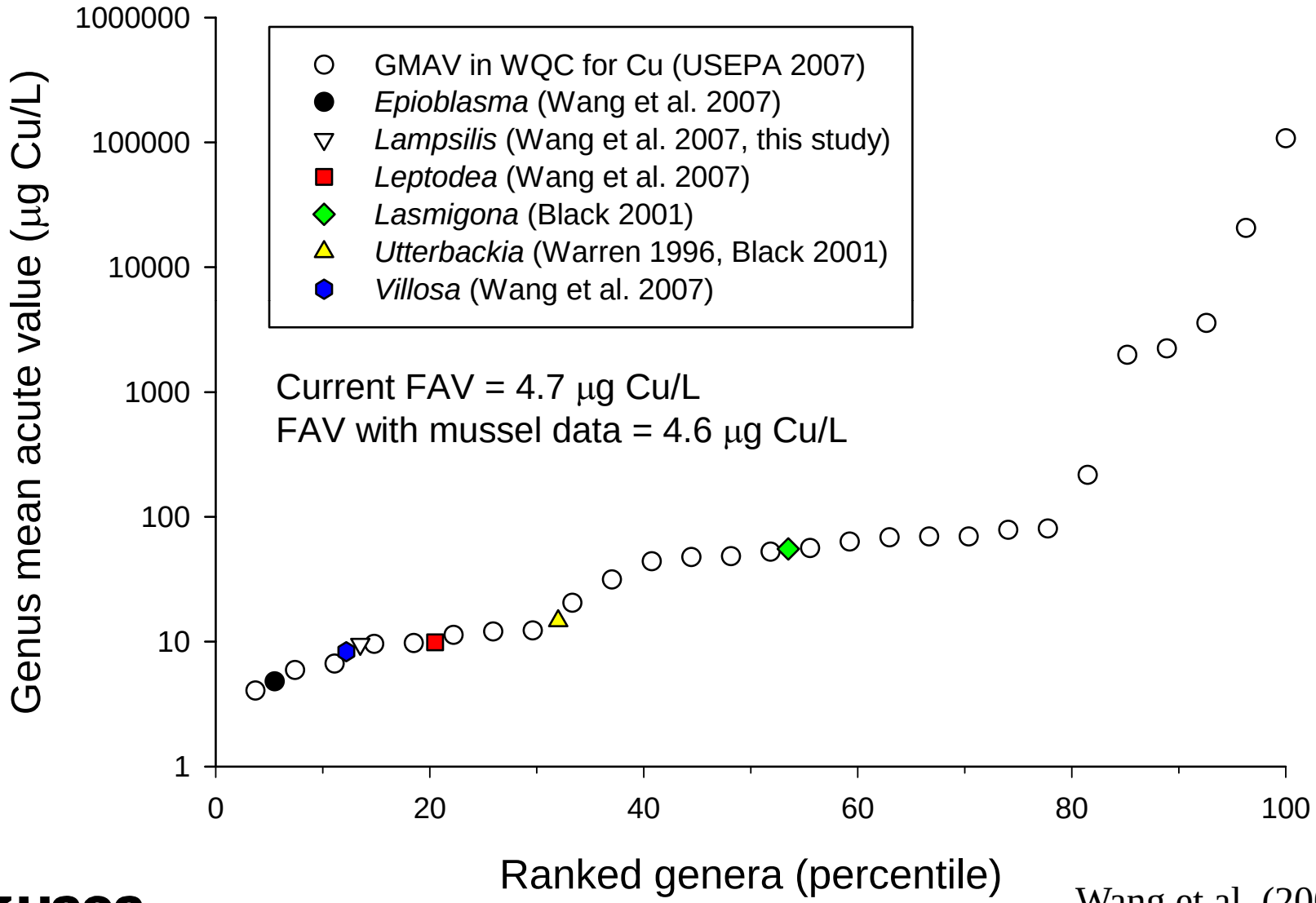
Wang et al. (2007a)

Chronic values and IC10 for survival and growth of mussels at the end of 28-d copper tests



Wang et al. (2007b)

Ranked genus mean acute values (GMAVs) in the USEPA water quality criteria for copper, with six GMAVs for mussels



Wang et al. (2009)

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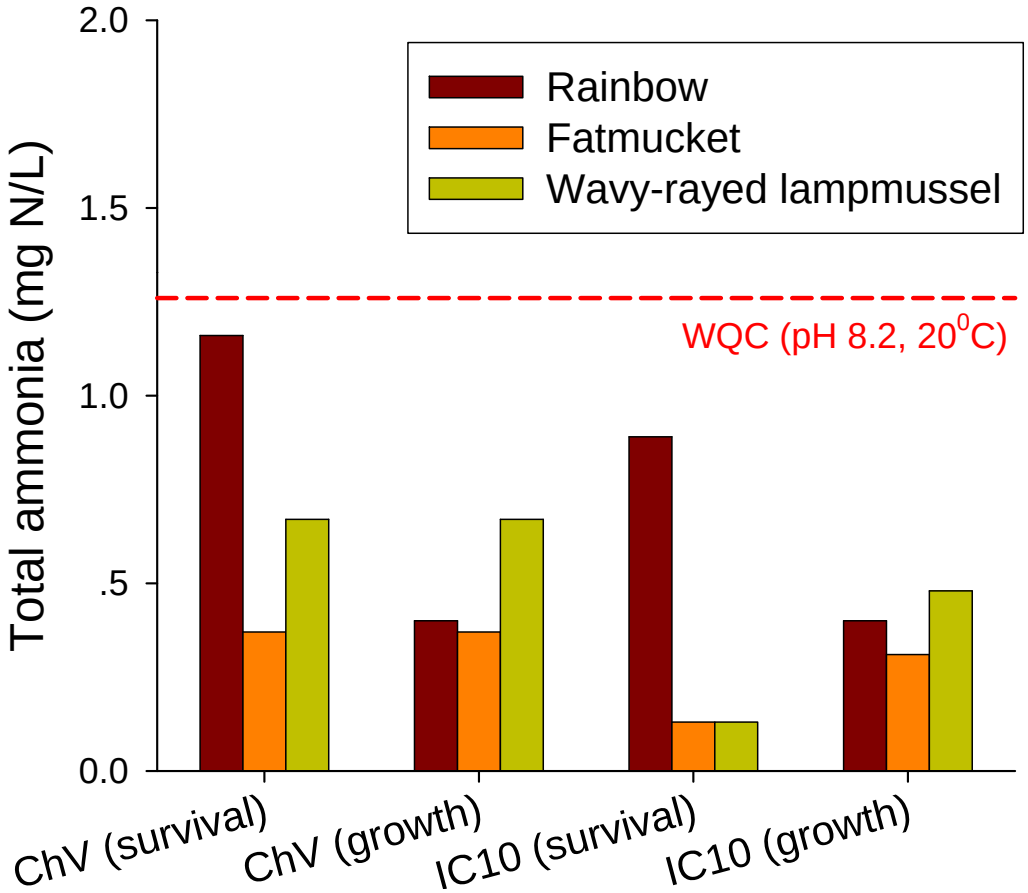
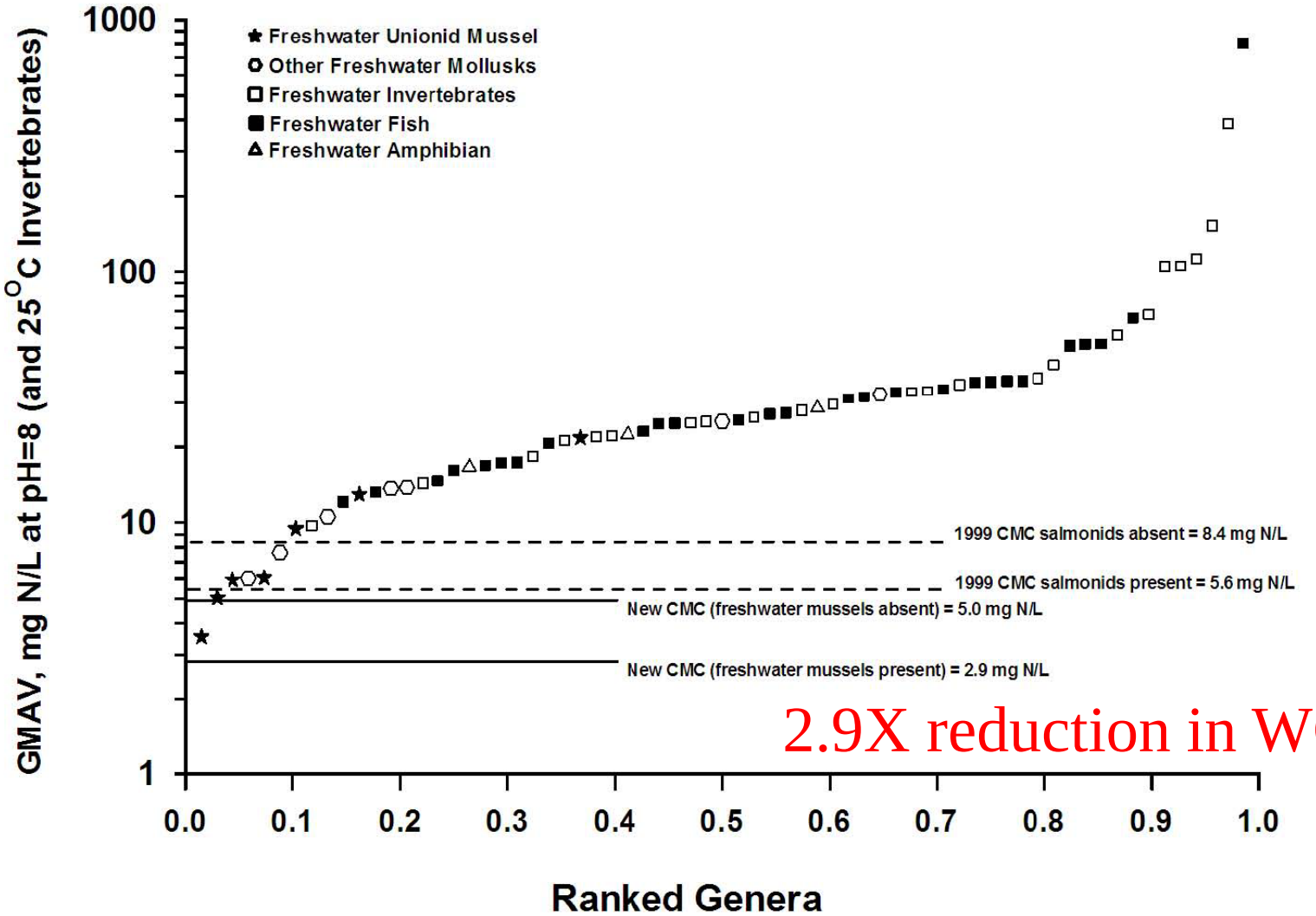


Wang et al. (2007b)

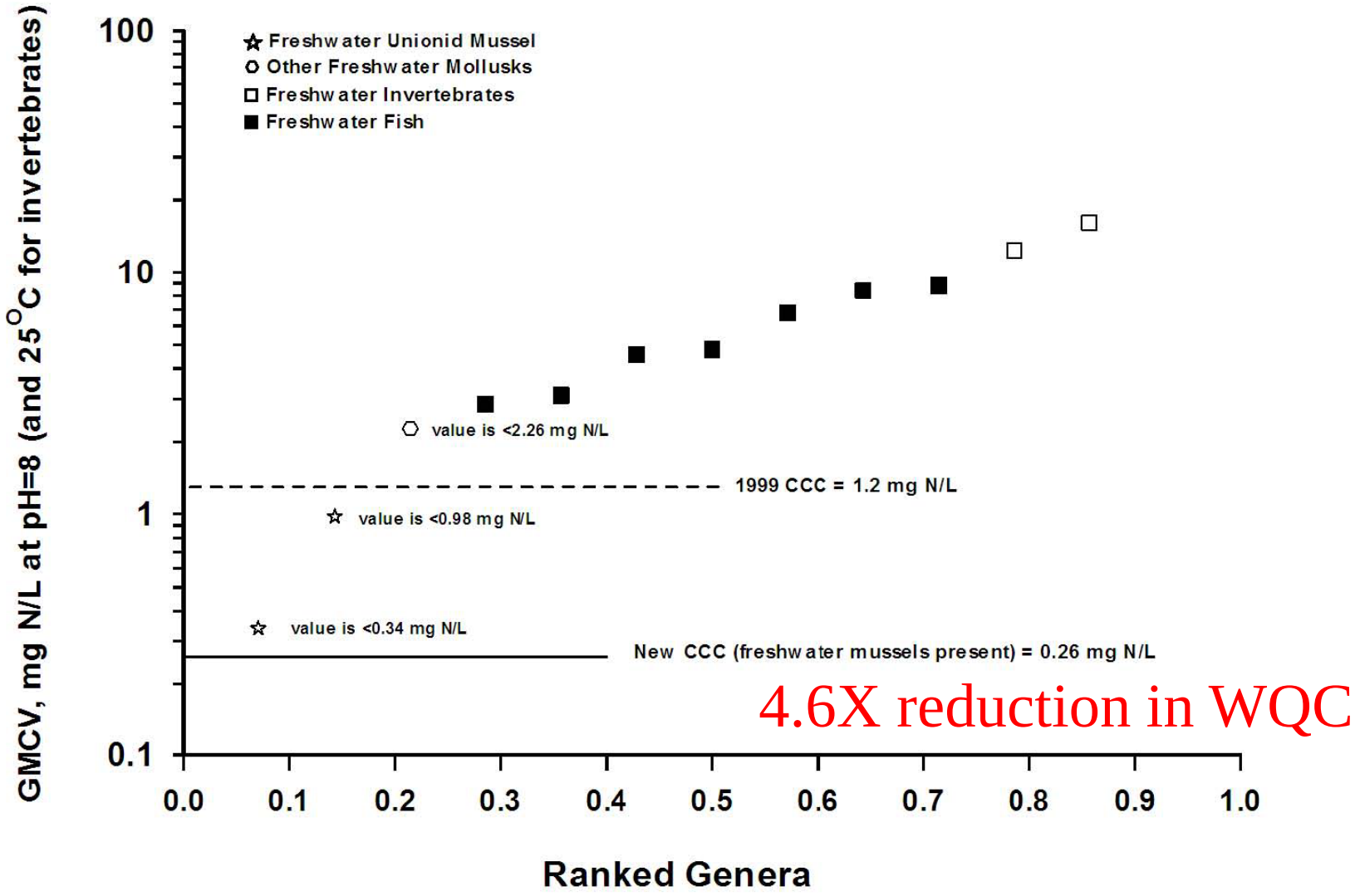
USEPA 2009 Draft revision to ammonia WQC: Acute



2.9X reduction in WQC

USEPA (2009)

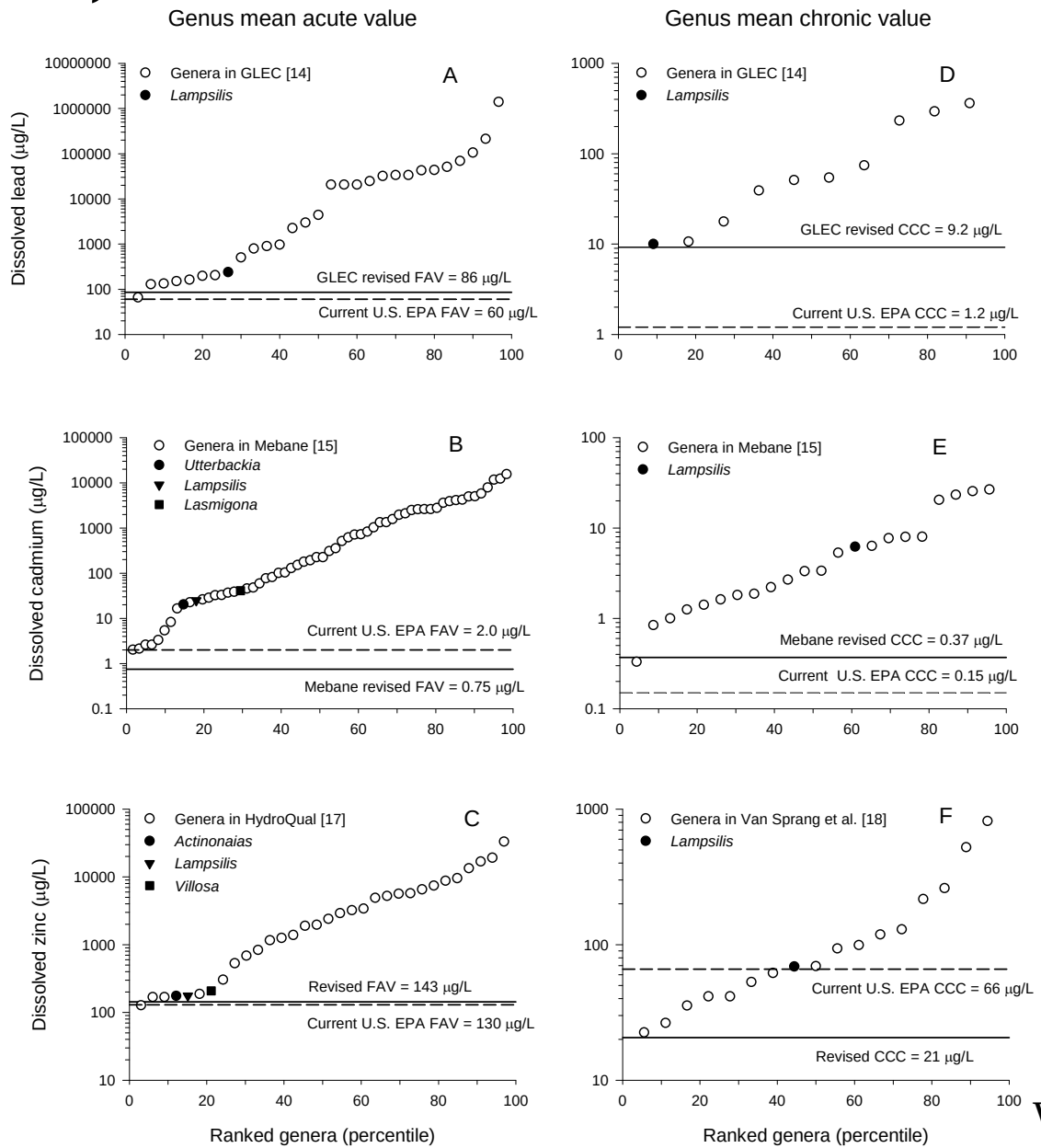
USEPA 2009 Draft revision to ammonia WQC: Chronic



4.6X reduction in WQC

USEPA (2009)

Acute and chronic sensitivity of mussels to lead, cadmium, zinc



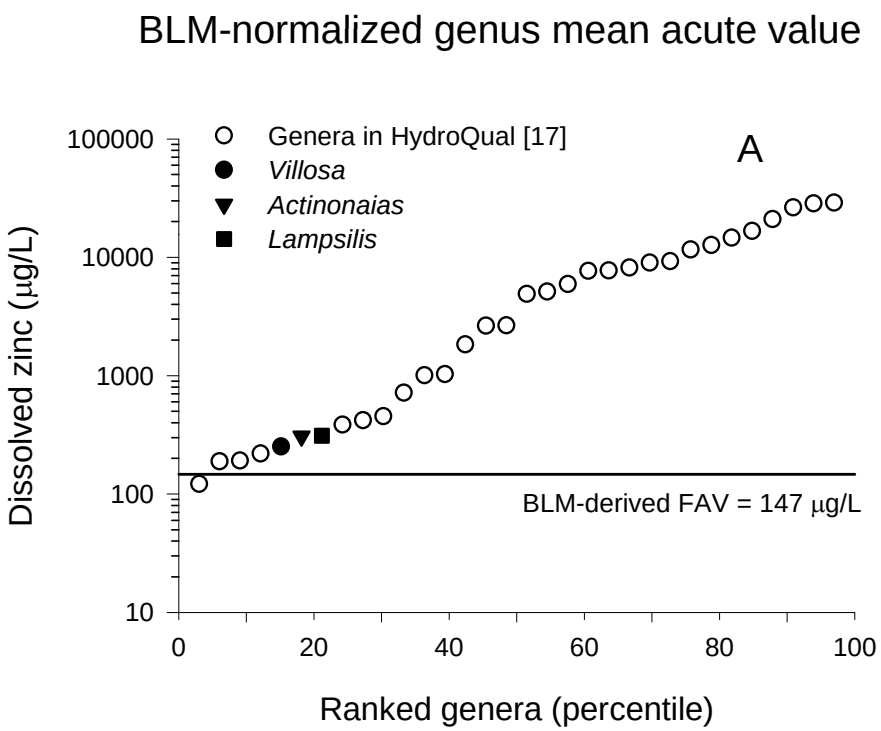
Lead

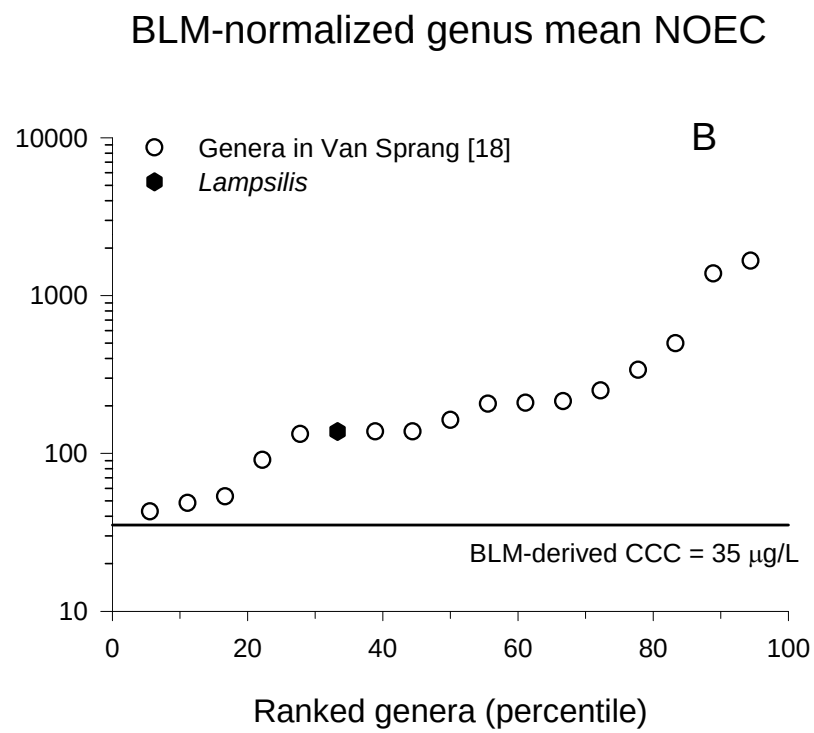
Cadmium

Zinc

Wang et al. (2010a)

Mussel sensitivity to zinc: Biotic Ligand Model





Wang et al. (2010a)

12 WQC comparisons…

Criteria	GMAVs in WQC	GMAVs w/mussels	Lowest mussel rank (1 = most sensitive)
Ammonia	34	42	1 (1, 2, 3, 4)
Atrazine (draft)	17	21	15
Chlorine	28	35	2 (2, 5, 9, 14)
Chlorpyrifos	15	16	13
Copper	43	57	1 (1, 2, 3, 5)
Diazinon	20	21	21
Mercury	29	30	10
Nonylphenol	15	21	13
PCP	32	37	17

Wang et al. (2010): Zinc, Lead, Cadmium; Besser et al. (2010): Nickel

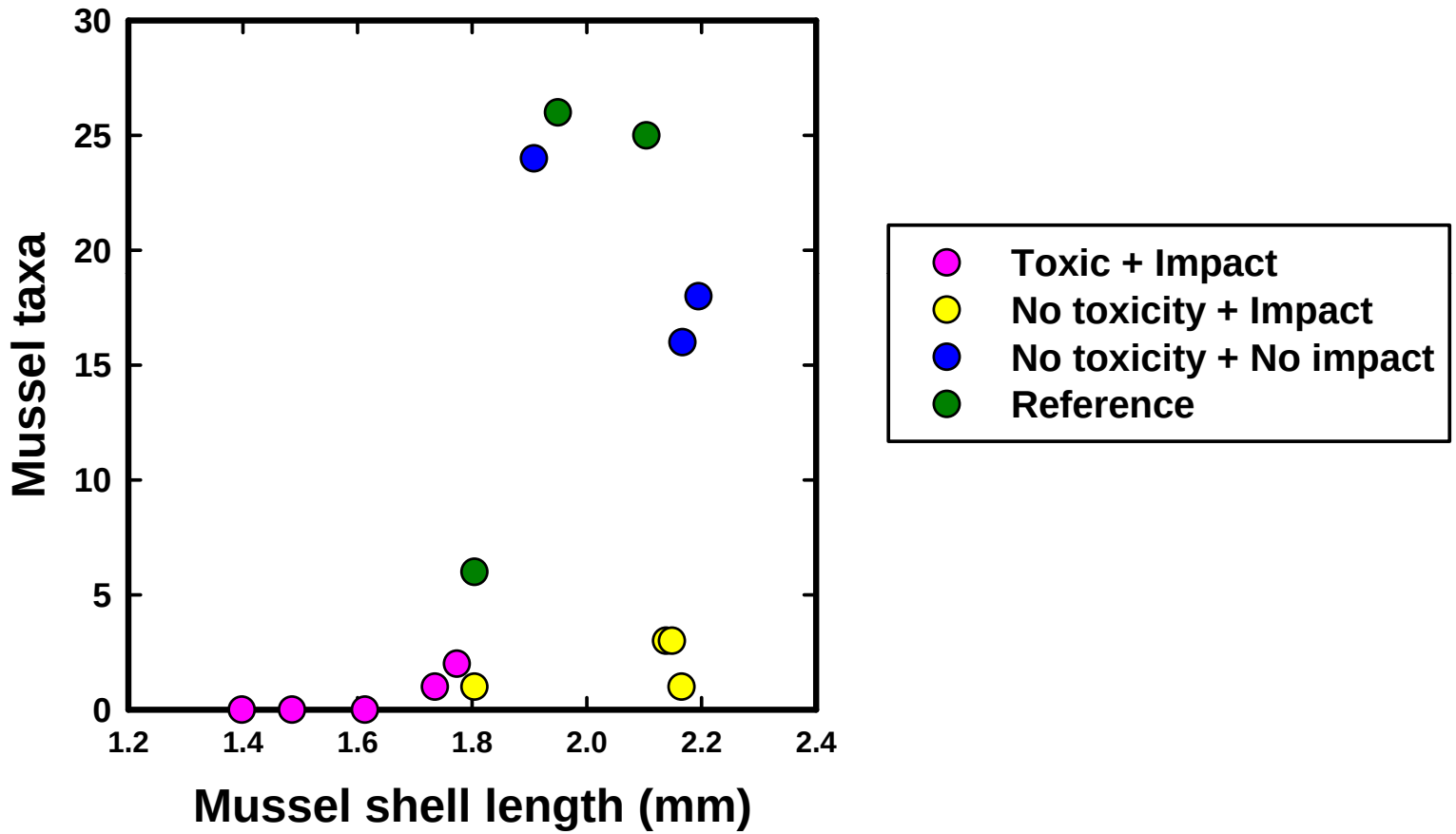
Test conditions for conducting sediment toxicity tests with amphipods and midge (ASTM E1706, USEPA 2000) and with mussels (adapted from ASTM E2455)

Conditions	***Hyalella***	**Midge**	**Mussels**
Test type:	Whole sediment (or water)		
Temperature (^{o}C):	23		
Chamber (ml):	300		
Sediment volume (ml)*:	100 (<0.25 mm sieve with mussels*)		
Photoperiod:	16:8 light:dark		
Water volume renewal:	2/d		
Age:	7 d		2 to 4 month*
Number organisms:	10		
Replicates:	4 to 12	4 to 16	4
Feeding:	YCT	Tetrafin	Algae
Overlying water:	100 (hardness as $CaCO_3$)		
Overlying water quality:	DO, ammonia, pH, hardness, alkalinity, conductivity		
Test duration (d):	10 to 42	10 to 60	28
Endpoints:	SGBR	SGBER	SGB
Test acceptability:	>80% (S)	>70% (S)	80%(S)

USGS

***Age versus size? No sieving with mussels >2 mm at start of exposures?**

Impacts on mussels at metal-contaminated sites in Missouri: Lab vs. field responses



USGS

Besser et al. (2009)

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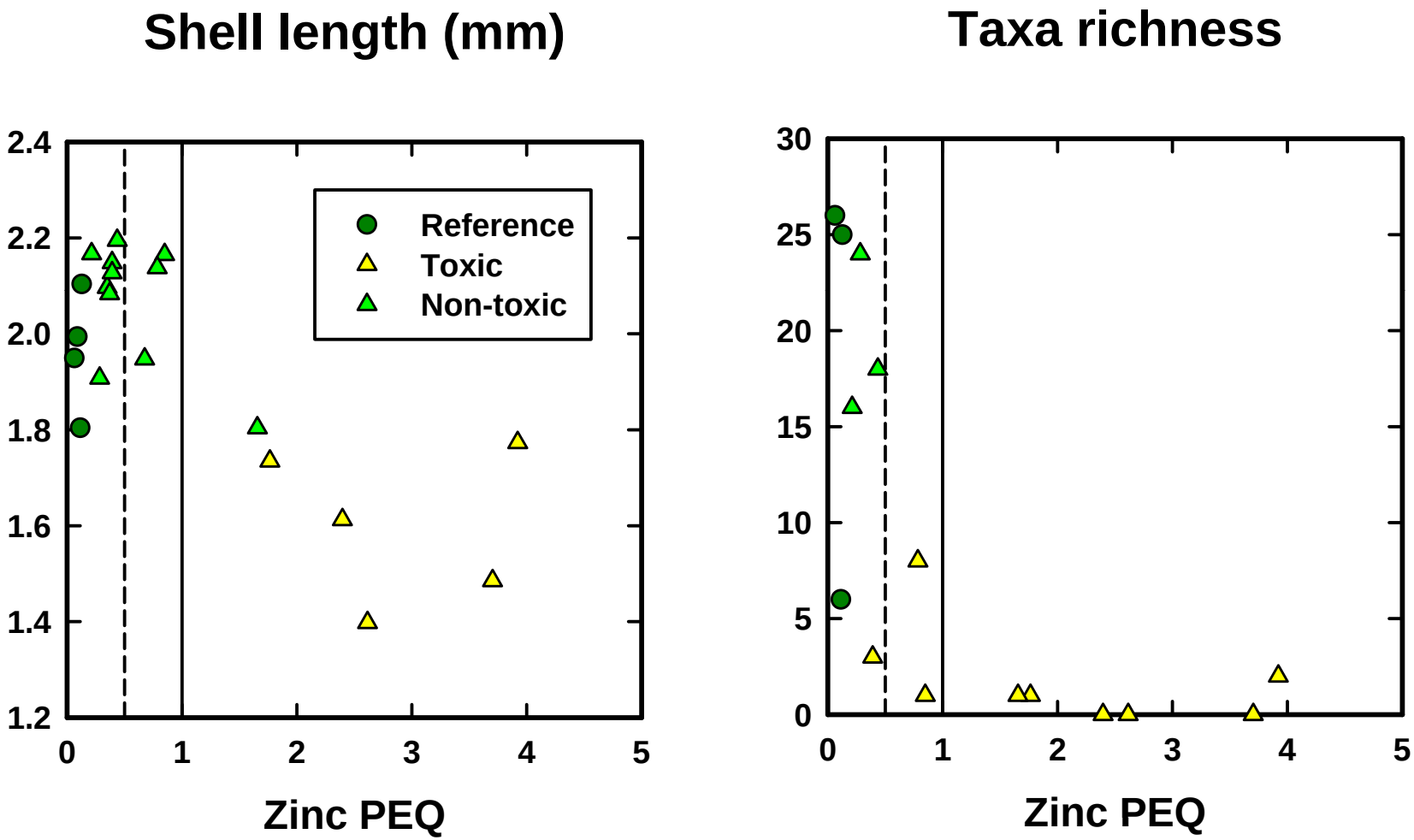
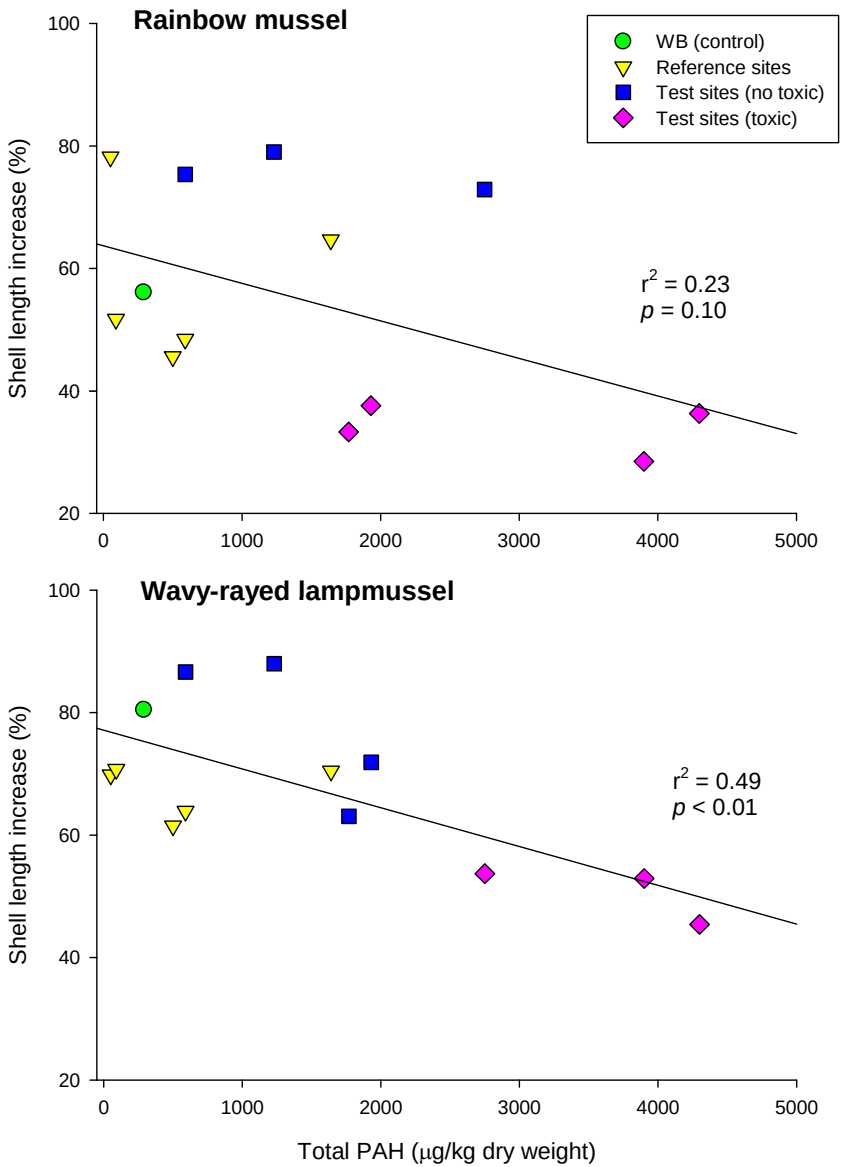


[yellow symbol = below reference envelope]

USGS

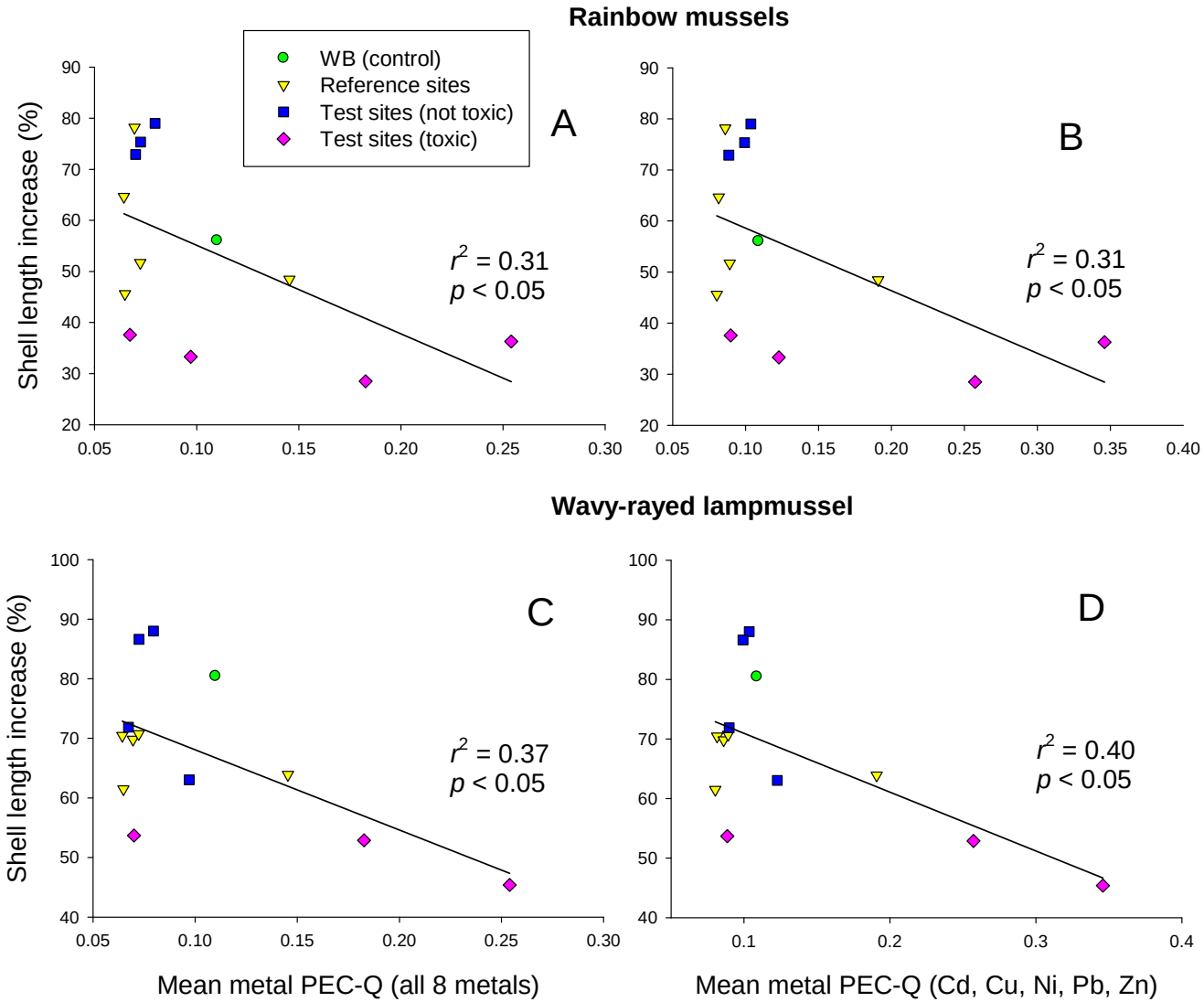
Besser et al. (2009)

Impacts on mussels at coal-impacted sites in Virginia and in Tennessee: PAHs in sediment



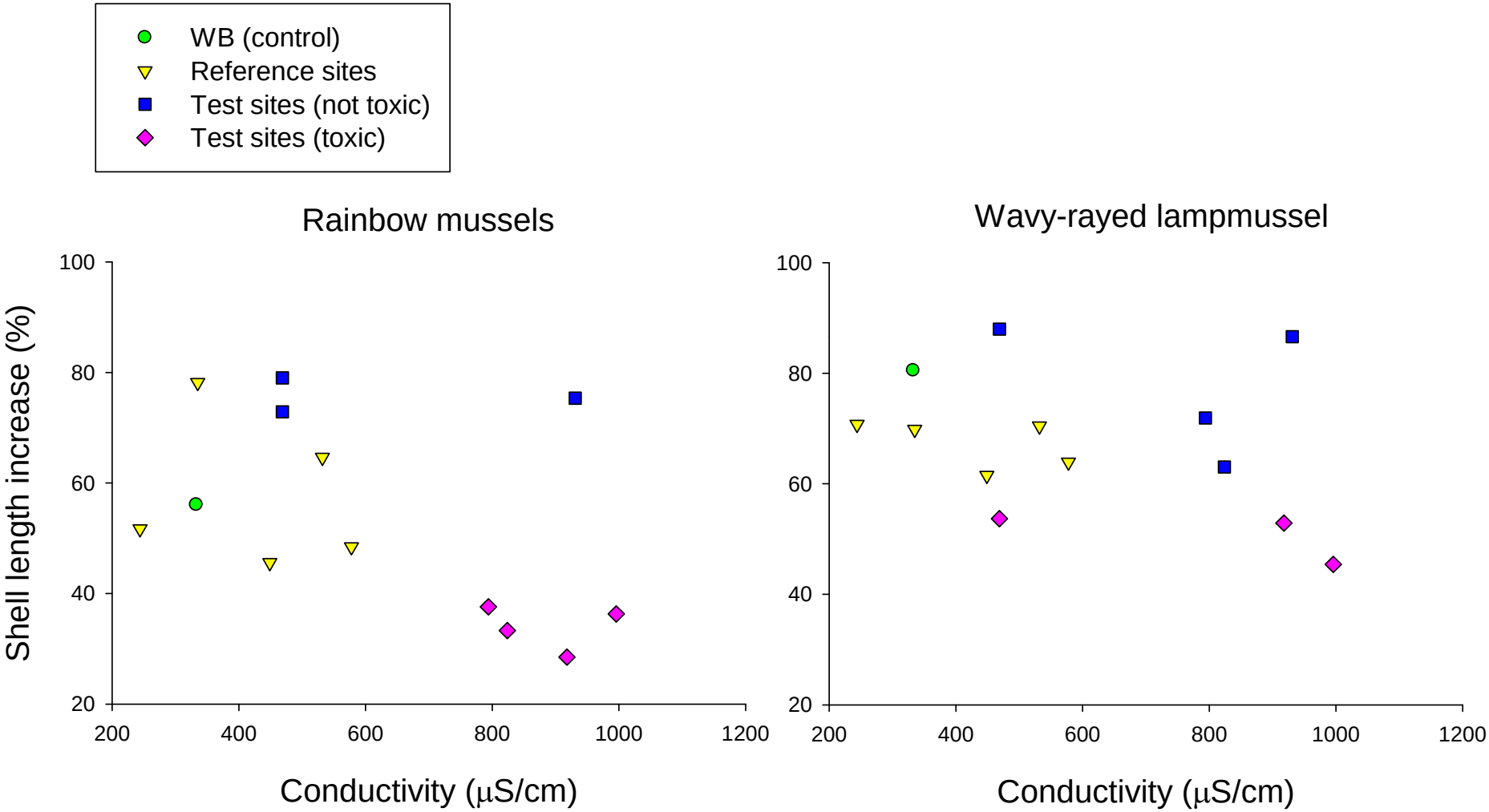
Wang et al. (2010b)

Impacts on mussels at coal-impacted sites in Virginia and in Tennessee: Metals in sediment



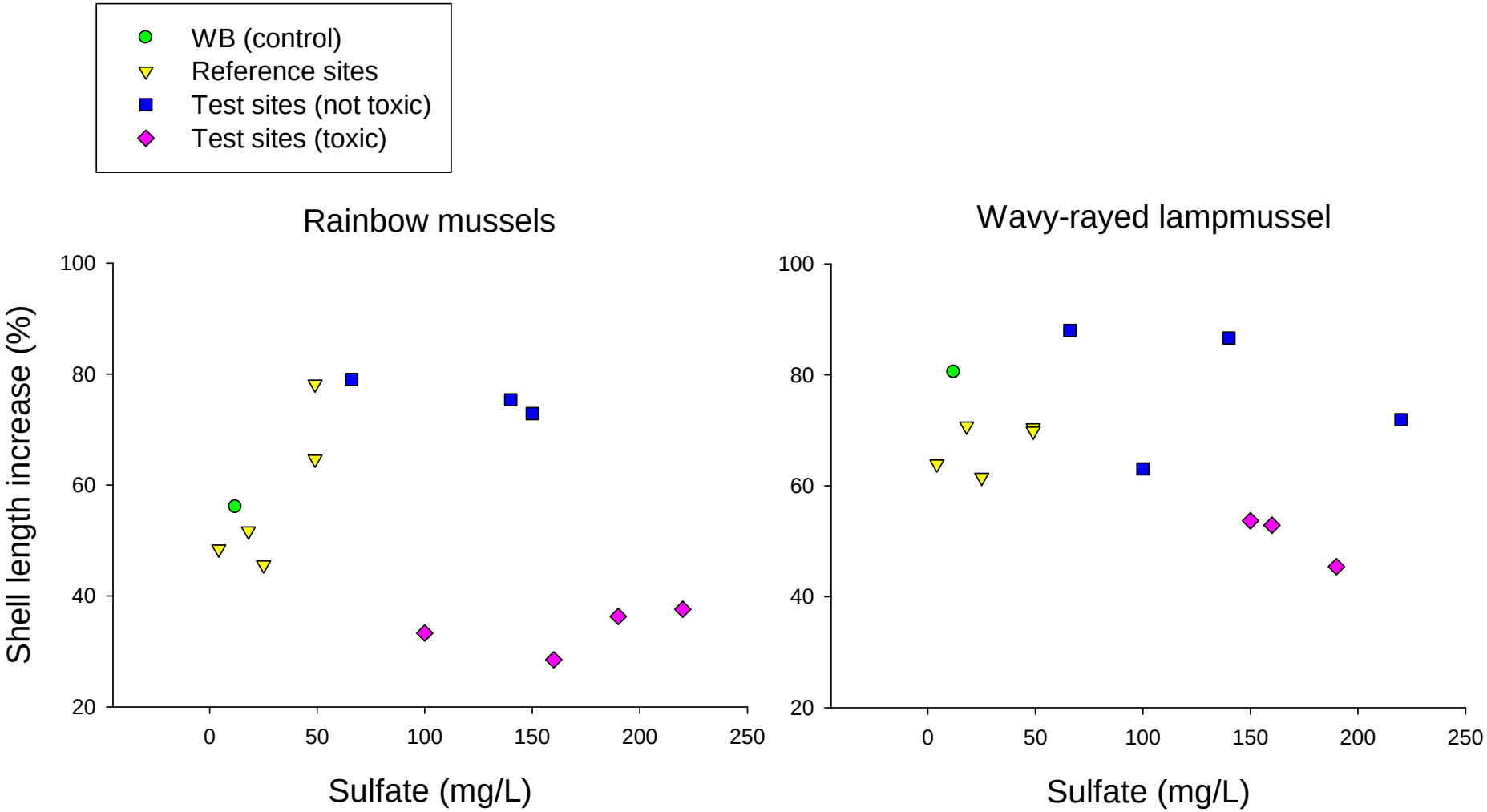
Wang et al. (2010b)

Impacts on mussels at coal-impacted sites in Virginia and in Tennessee: Pore-water conductivity



Wang et al. (2010b)

Impacts on mussels at coal-impacted sites in Virginia and in Tennessee: Pore-water sulfate



Wang et al. (2010b)