Use of a Dietary Dose Model for Evaluating Risks to Fish from Exposure to Regulated Metals

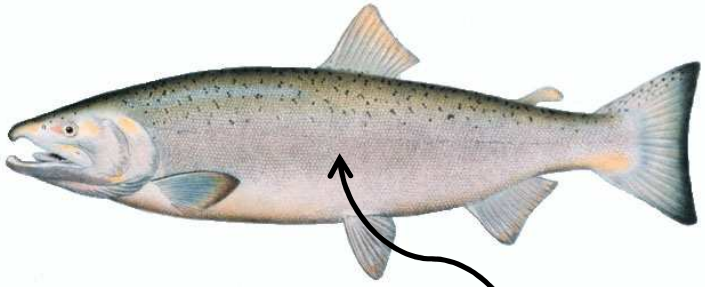
Matt Luxon and David DeForest

Windward Environmental LLC

ERA: Multiple Lines of Evidence

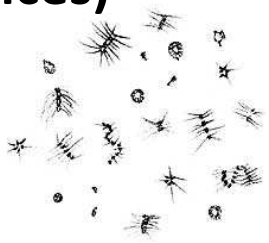
Metals in Surface Water

(ambient water quality criteria, bioassays, fish community indices)



Metals in Diet

Metals in Tissue



Metals in Sediment

(sediment quality guidelines, bioassays, benthic community surveys)

Issue

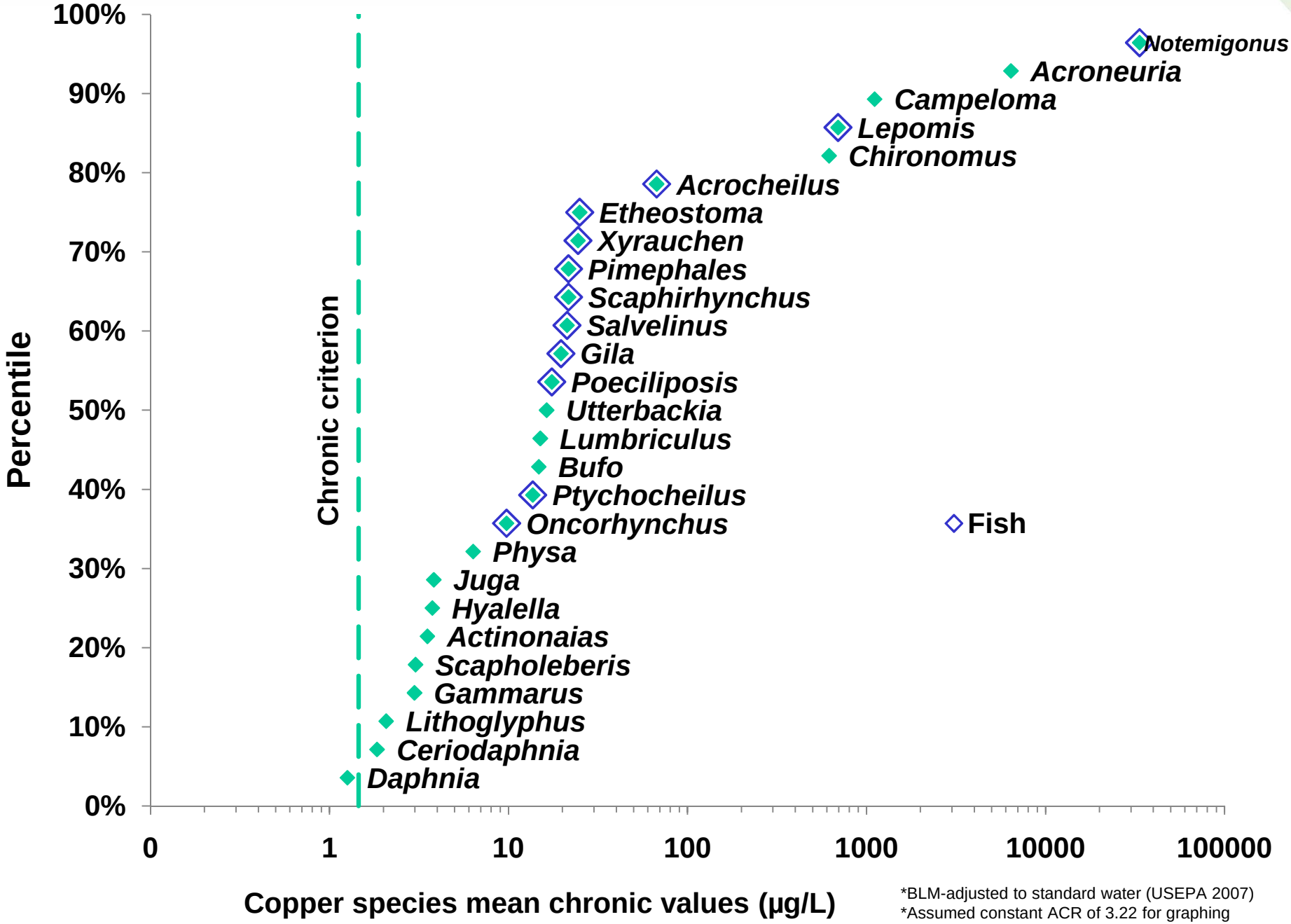
In screening-level ecological risk assessments (ERA), the fish dietary line of evidence (LOE) is more sensitive than water or sediment LOEs for metals, indicating that:

- Fish are more sensitive to metals toxicity through dietary exposure than benthic invertebrates are through water and sediment exposure pathways, or
- The fish dietary LOE is overpredicting hazard

Assessing Risk to Fish from Metals

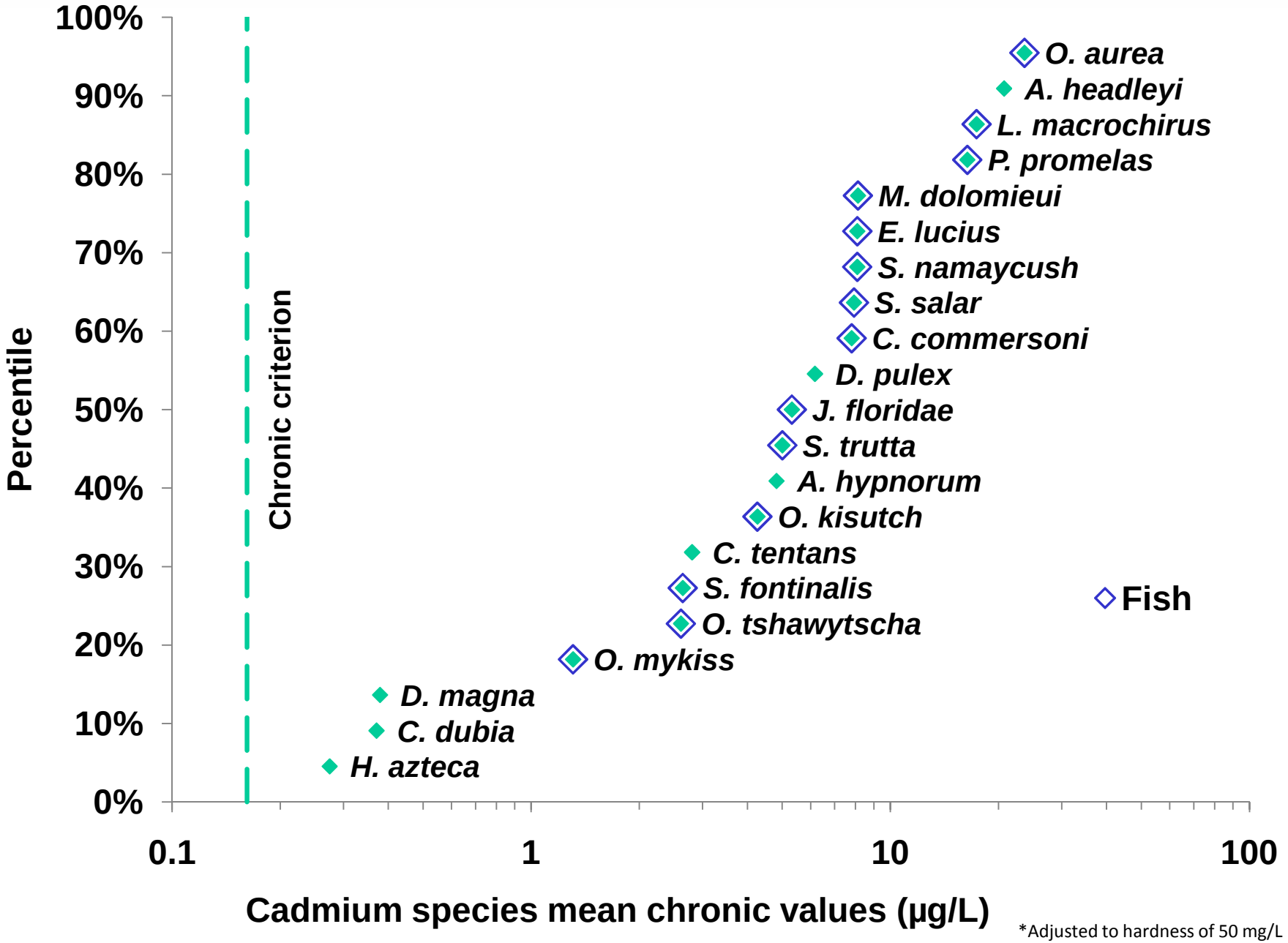
- Mercury, selenium, and butyltins
  - Dietary exposure pathway is significant
  - Tissue burdens are generally predictive of toxicity
  - Assessed through comparison of tissue burdens with residue effects data
- Arsenic, Cadmium, Copper, Lead, etc.
  - Typically assessed through water line of evidence
    - Based on lots of data
    - Approach is protective of aquatic life in general
    - Protectiveness of dietary exposure route is uncertain

Chronic SSD for Copper



*BLM-adjusted to standard water (USEPA 2007)
*Assumed constant ACR of 3.22 for graphing

Chronic SSD for Cadmium



*Adjusted to hardness of 50 mg/L

If metals concentrations are below water quality criteria and sediment quality guidelines, are fish protected from dietary toxicity?

Dietary Approaches

$$HQ = EPC / TRV$$

Dietary Concentration Approach

$$EPC = C_{prey} \times F_{prey} + C_{sed} \times F_{sed}$$

Dietary Dose Approach

$$EPC = \frac{C_{prey} \times F_{prey} \times FIR + C_{sed} \times F_{sed} \times SIR}{BW}$$

Where:

BW = body weight (kg)

C_{prey} = concentration in prey (mg/kg ww)

C_{sed} = concentration in sediment (mg/kg dw)

EPC = exposure point concentration (mg/kg) or (mg/kg bw/day)

FIR = food ingestion rate (kg/day)

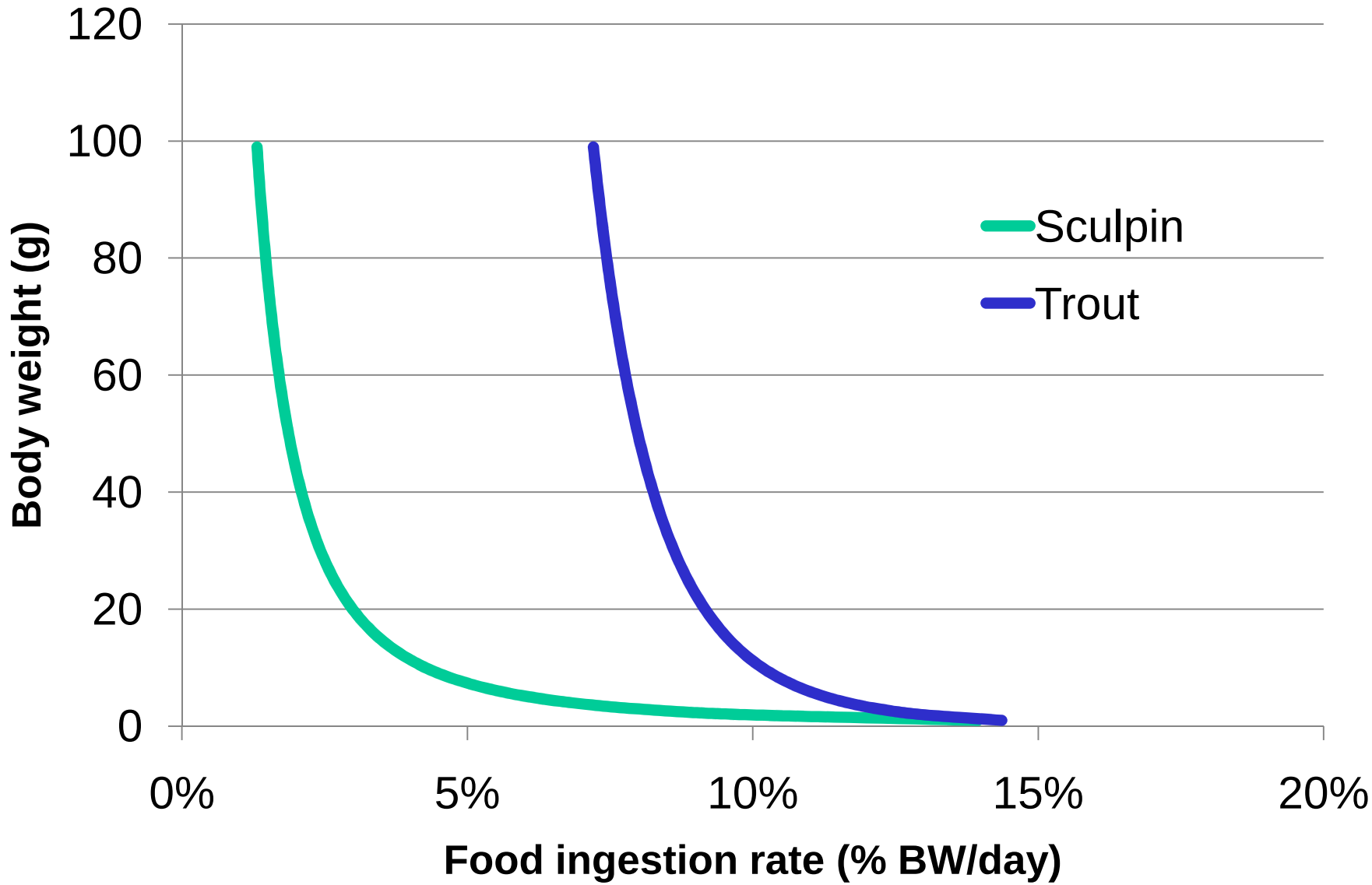
F_{prey} = fraction of prey item in diet

F_{sed} = fraction of sediment in diet

HQ = hazard quotient

SIR = sediment ingestion rate (kg/day)

Food Ingestion Rates



Moss JHH. 2001. Development and Application of a Bioenergetics Model for Lake Washington Prickly Sculpin (*Cottus asper)* MS thesis. University of Washington, Seattle, WA, USA

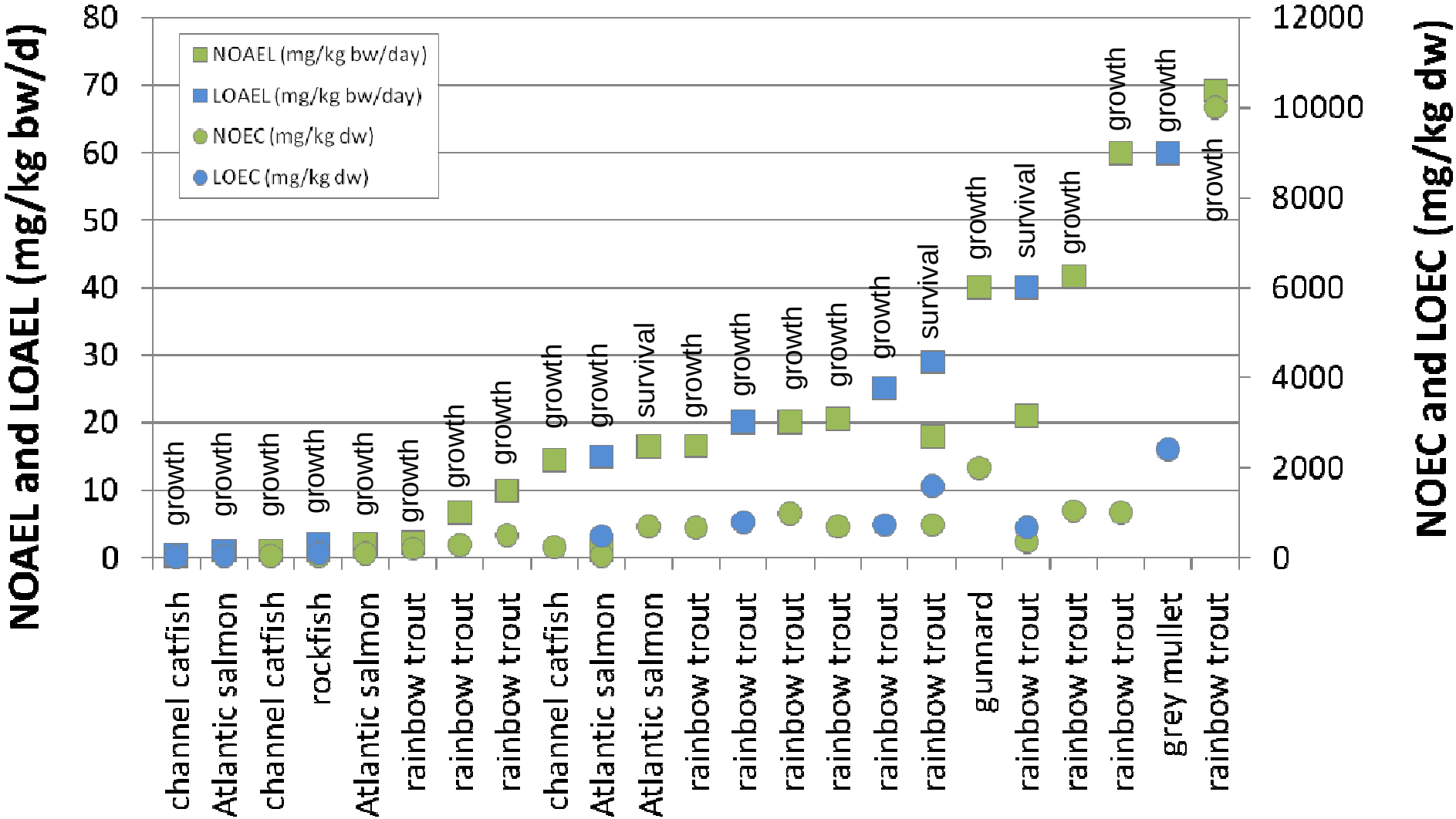
Weininger D. 1978. Accumulation of PCBs by lake trout in Lake Michigan. PhD thesis. University of Wisconsin, Madison, WI, USA.

Fish Dietary Toxicity Data

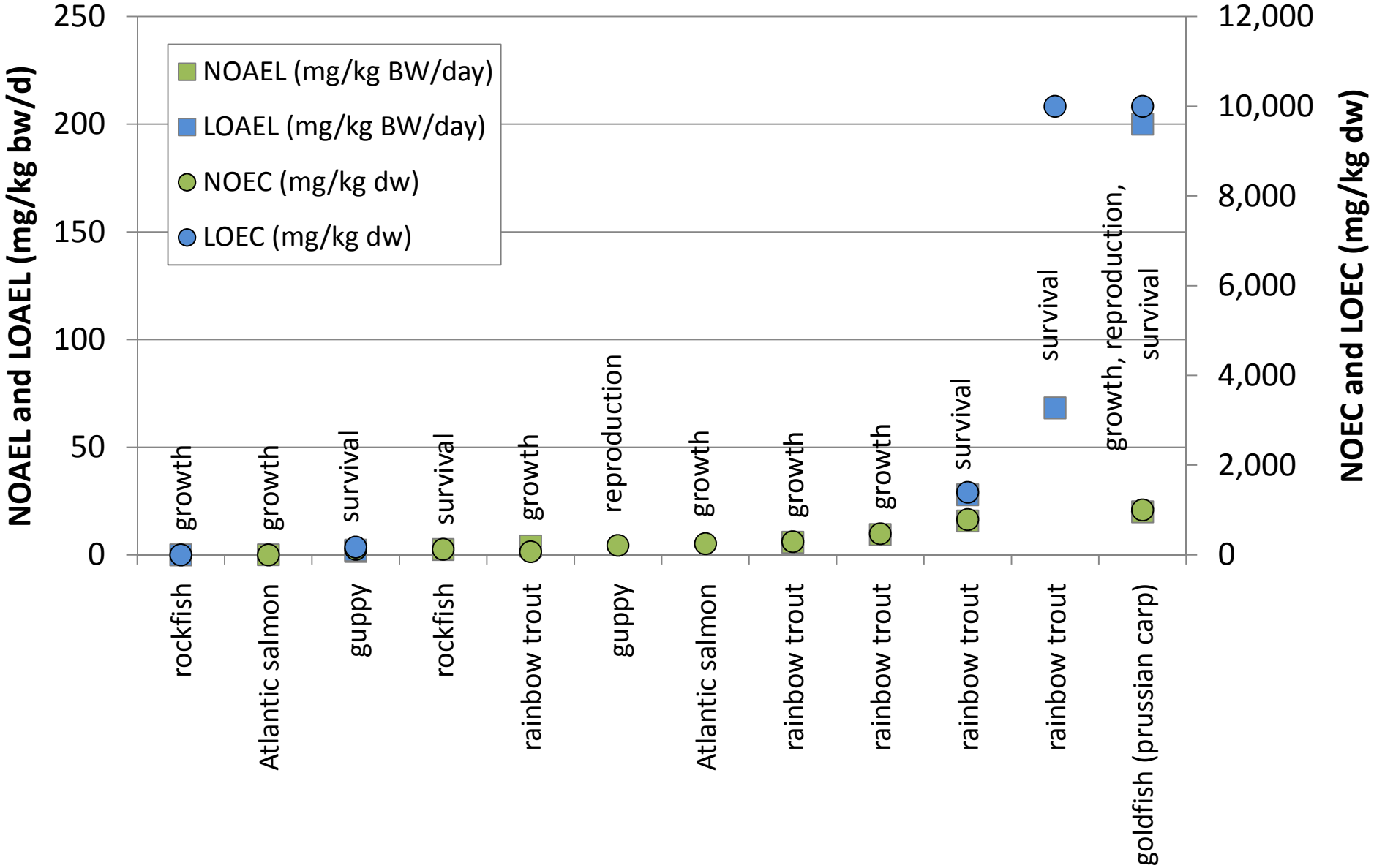
Metal	Studies	Reported FIR	LOAELs	NOAELs	Species
Aluminum	1	1	0	1	1
Antimony	0	0	0	0	0
Arsenic	5	5	10	5	2
Cadmium	11	8	5	10	5
Chromium	0	0	0	0	0
Copper	19	16	9	16	5
Lead	2	1	0	2	1

FIR – food ingestion rate
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level

Fish Dietary Effects Data - Copper



Fish Dietary Effects Data - Cadmium



If metals concentrations are below water quality criteria and sediment quality guidelines, are fish protected from dietary toxicity?

Comparison of Water, Sediment, and Dietary Dose HQs

- Hypothesis: Because invertebrates are generally more sensitive than fish to inorganic metals:
  - Metals HQs for water and sediment LOEs are higher than HQs for the fish dietary LOE.
  - If metals screen out for water and sediment LOE, they also screen out for fish dietary LOE.

Methods

- Collected data from published literature and online data repositories
- Compared sediment metals concentrations to probable effects concentrations (PECs)
- Compared dissolved aqueous metals to hardness adjusted chronic ambient water quality criteria
- Compared invertebrate tissue metals concentrations to lowest fish dietary LOEC
- Compared calculated metals daily doses for a 1-g sculpin to lowest fish dietary dose LOAEL

Number of Samples with Metals Data by Medium

Medium	Number of Samples	
	Cadmium	Copper
Water	23	27
Sediment	22	22
Prey	26	30

Number of Samples Where Dose HQ Exceeded Media HQ

Media	No. of Samples where Media HQ < 1 and Dose >1/ No. of Samples where Media HQ<1	
	Cadmium	Copper
Water	21/23	24/27
Sediment	22/22	21/22
Prey	26/26	30/30

Number of Samples Where Media HQ < 1 and Dose HQ > 1

Media	No. of Samples where Media HQ < 1 and Dose >1/ No. of Samples where Media HQ<1	
	Cadmium	Copper
Water	5/5	13/16
Sediment	16/16	12/14
Prey	0/0	13/17

Issue

In screening-level ecological risk assessments (ERA), the fish dietary line of evidence (LOE) is more sensitive than water or sediment LOEs for metals, indicating that:

- Fish are more sensitive to metals toxicity through dietary exposure than benthic invertebrates are through water and sediment exposure pathways, or
- The fish dietary LOE is overpredicting hazard

Number of Samples Where Media HQ < 1 and Rainbow Trout Dose HQ > 1

Media	No. of Samples where Media HQ < 1 and Dose >1/ No. of Samples where Media HQ<1	
	Cadmium	Copper
Water	0/5	2/16
Sediment	0/16	3/14
Prey	0/26	0/17

Uncertainty

- Factors that affect fish dietary toxicity
  - Fish size
  - Water quality (e.g., temperature, pH, hardness)
  - Food nutritional quality (e.g., prey species, protein and lipid content)
  - Chemical form of metals
  - Gut chemistry
    - pH
    - Competing ligands

Conclusions and Recommendations

The fish dietary LOE is overpredicting hazard

- Fish dietary metals toxicity data should not be used to identify COPCs at contaminated sites
- Only if other LOEs indicate potential metals toxicity, should dietary toxicity to fish be considered as a LOE for the site
- Rainbow trout data illustrate that the fish dietary LOE is consistent with water and sediment LOEs when species-specific toxicity data are available


Any
Questions?