Cadmium shipping, receiving and handling: Comparative bio-dynamics in stream insects.

David B. Buchwalter, Daniel J. Cain & Samuel N. Luoma
US Geological Survey, Menlo Park CA, USA

Clean Water Act: major disconnect

BIOASSESSMENT/ BIOMONITORING

TOTAL MAXIMUM DAILY LOADS

- it is currently difficult to bridge these 2 activities
- demonstrating that biological communities are impaired cannot trigger a TMDL

Why not ???

It is very difficult to infer the causes of biological impairment from bioassessment data..

Aquatic insects as indicators of ?

- Currently lacking stressor-specific bioassessment protocols…….because…..

- Currently lacking stressor-specific tolerance values.

Physiological approaches:

- provide a basis for understanding how species deal with different stressors.
- can reduce ambiguities associated with community-level responses to stressors in nature
- can be used towards the development of stressor-specific tolerance values

Aquatic insects as indicators of metal pollution

- In trace metal-contaminated streams, some insect species are absent while others persist
  - How can we tell if metals are the causal agent?
  - Which species are the best indicators of metal pollution?
  - Why / how are insects differentially sensitive to metals?

Major factors determining metal vulnerability

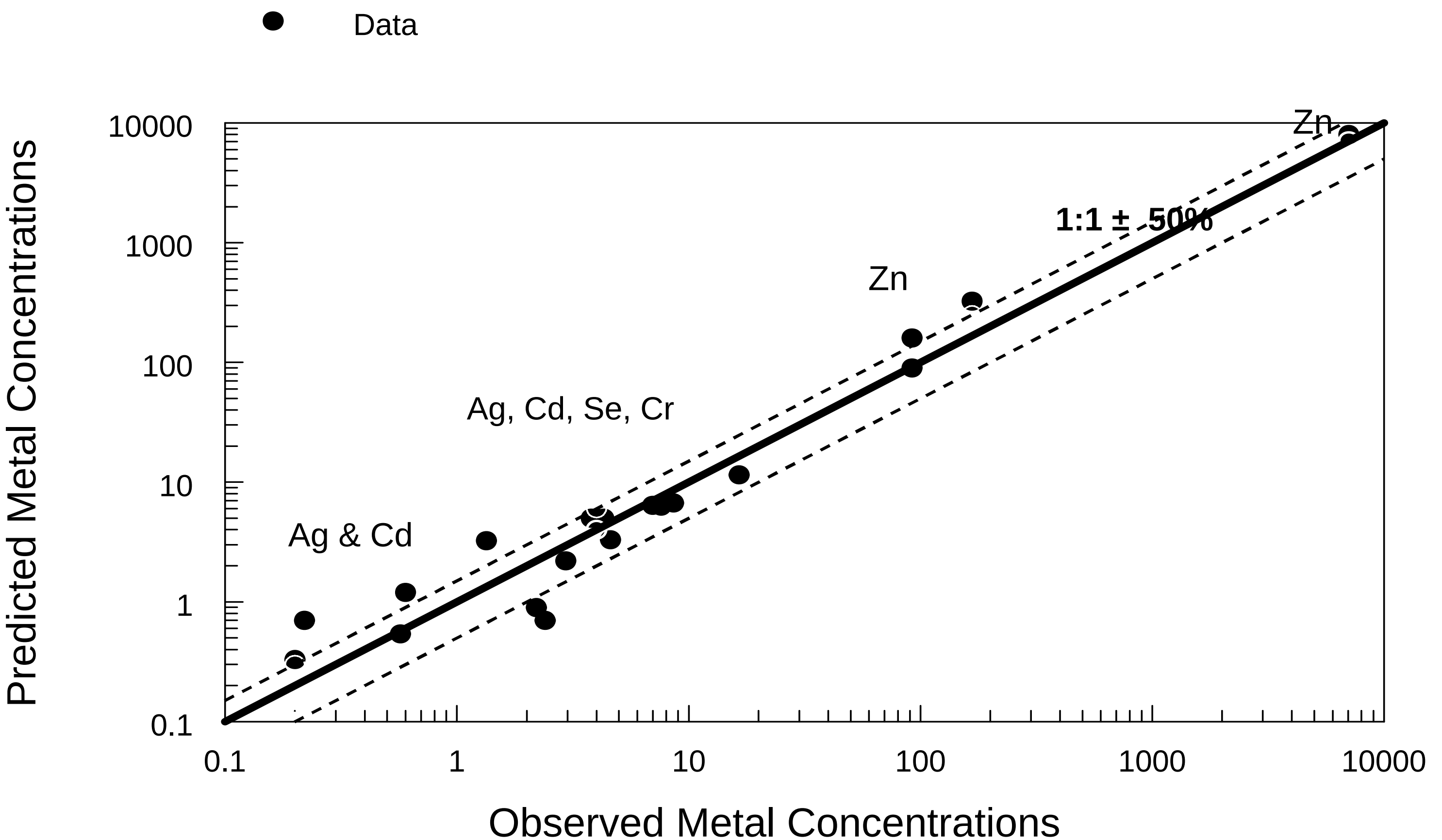
- Bioaccumulation (shipping / receiving)
  - accumulated body burden
- Detoxification and Storage (handling)
  - accumulated dose at target site(s)

Bioaccumulation patterns

- Differ widely among species
- Mechanisms poorly understood in stream insects
- Models have successfully predicted metal body burdens in nature from lab experiments
  - Dissolved accumulation rate constants (k_u)
  - Efflux rate constants (k_e)
  - Dietary accumulation (AE, IR)

DYMBAM Predictions vs. Observed

Molluscs, copepods, barnacles



Luoma and Rainbow, in prep.

Metabolic processes

- Sensitivity is determined by a combination of bioaccumulation patterns and other physiological processes
  - Detoxification (Metallothionein-like proteins)
  - Storage (granular storage)
    - e.g. barnacles can be up to 1% zinc

Experimental design

- Field collected species (9) were chosen to represent the major insect orders commonly focused upon in stream bioassessments:

Mayflies: Ephemeroptera

Stoneflies: Plecoptera

Caddisflies: Trichoptera

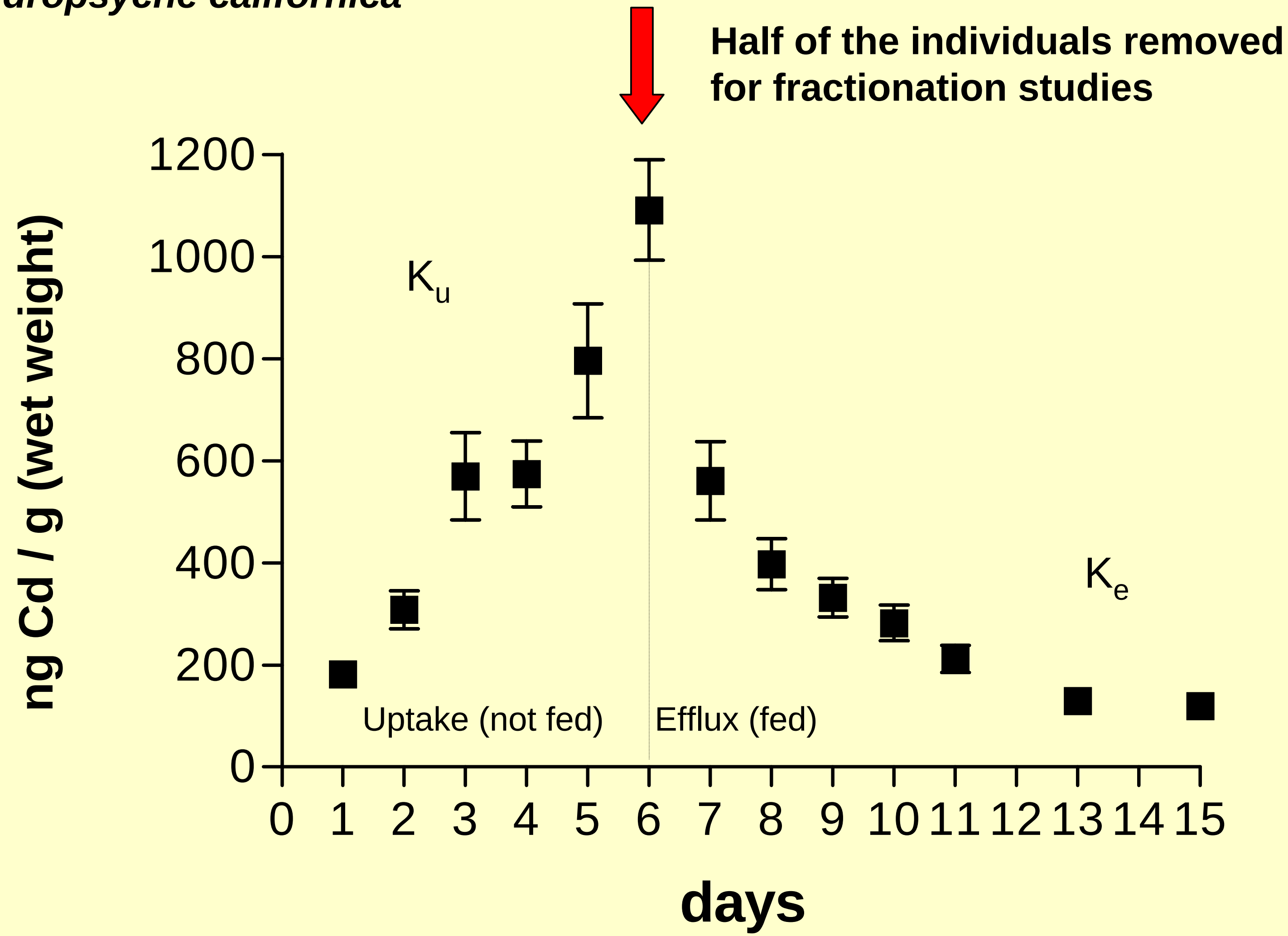
Note: % EPT taxa is a commonly used bioassessment metric

Experimental design

- Larvae were exposed to Cd (~500 ng / l) for 5-6 days (radiotracer experiment).
- At the end of the exposure period, half of the individuals were removed for sub-cellular fractionation studies.
- Remaining individuals were transferred to clean water for 9 days to measure efflux rate constants.

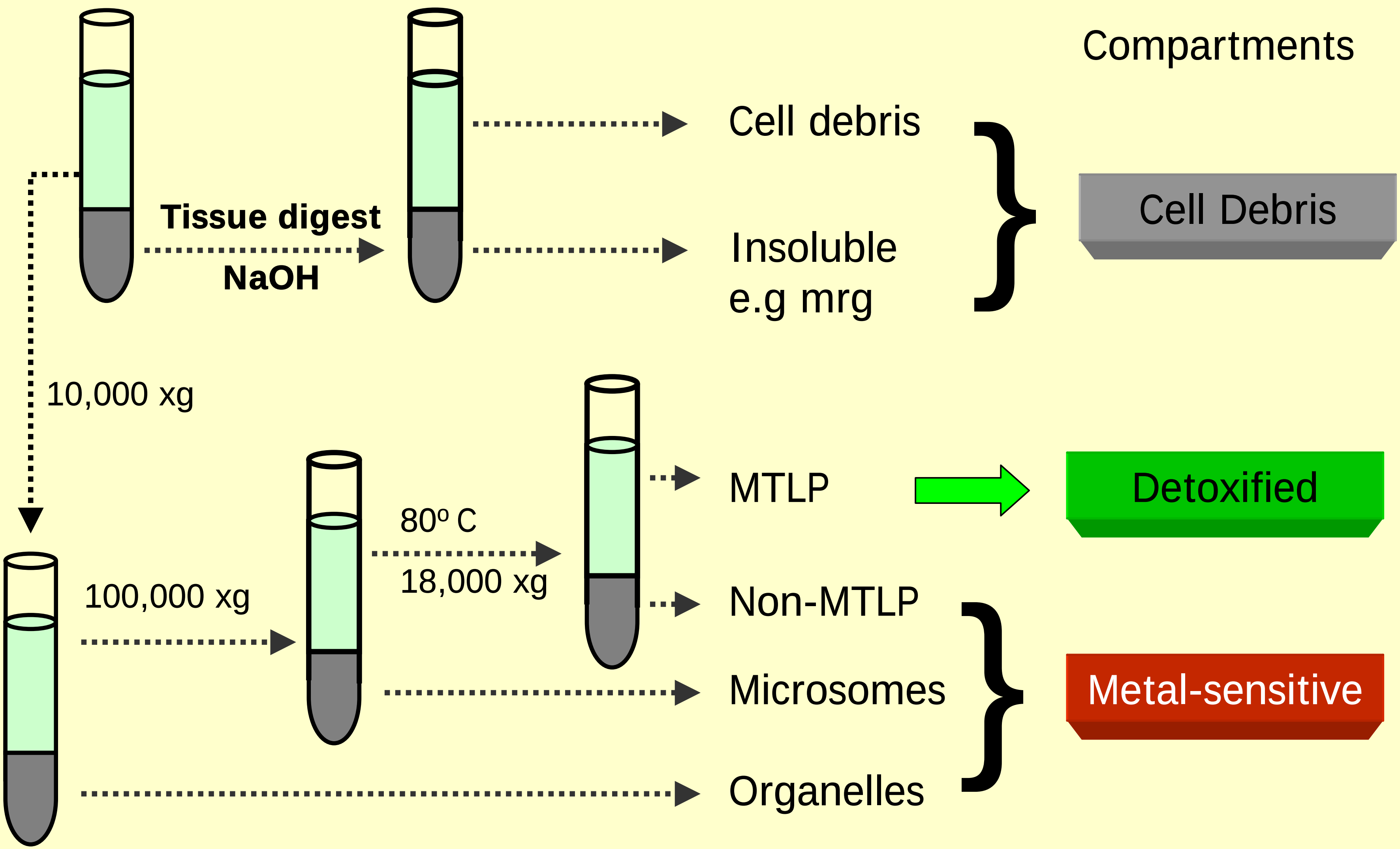
Experimental design

Hydropsyche californica

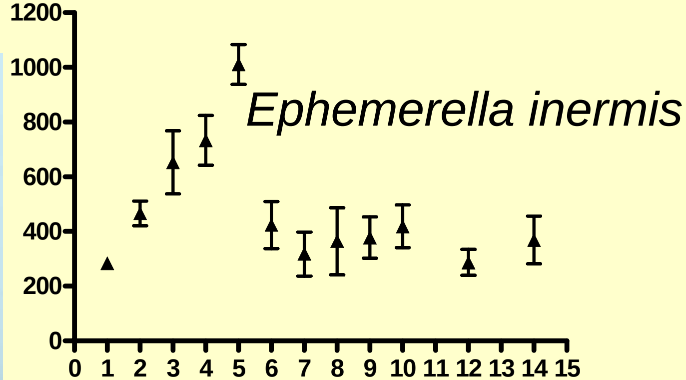


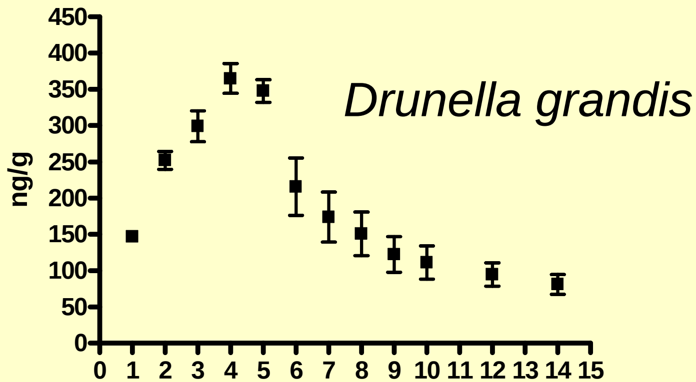
***In vivo* gamma counting allows us to follow individuals over time**

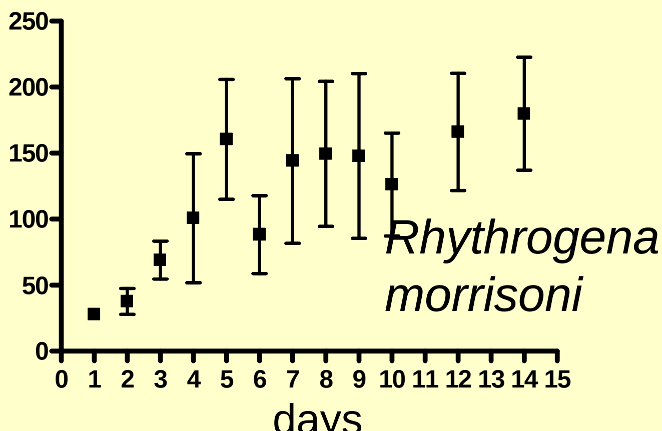
Subcellular Fractionation

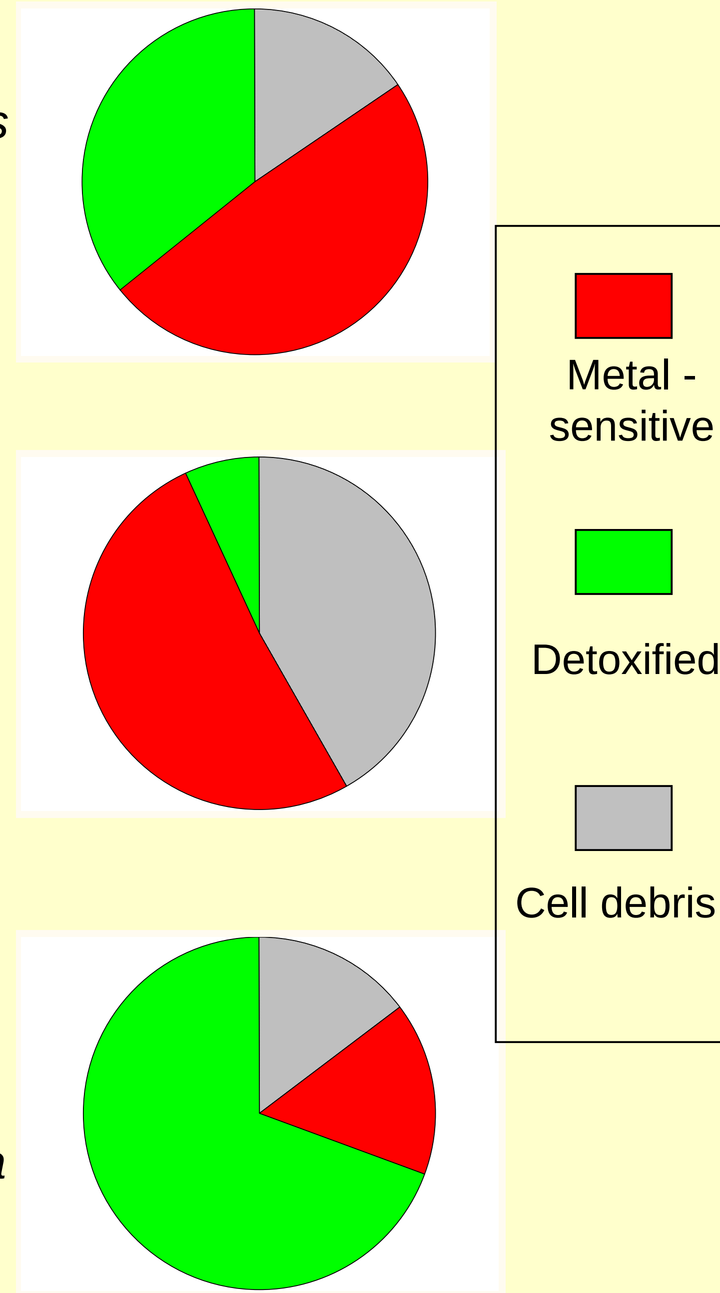


Ephemeroptera

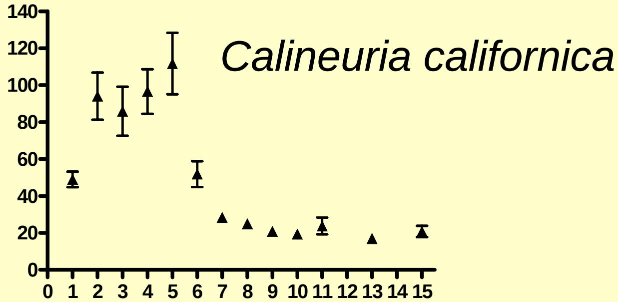


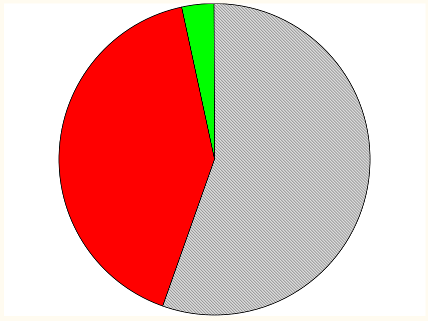


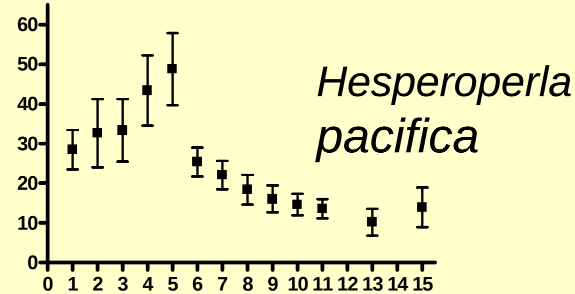


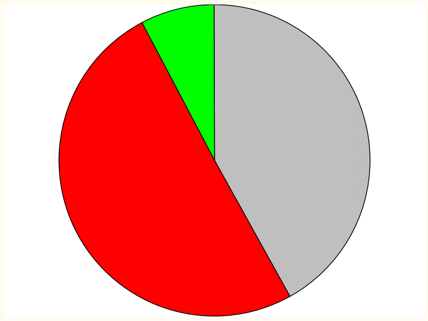


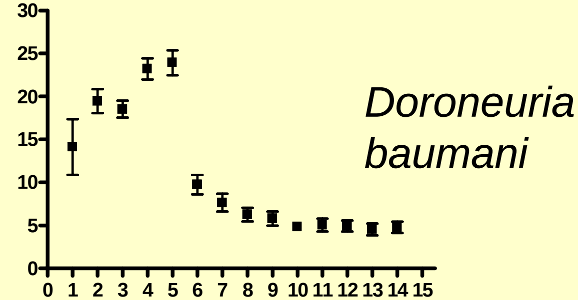
Plecoptera

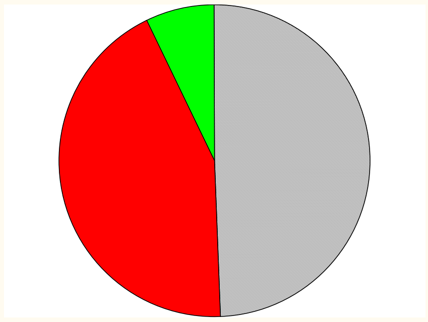

Calineuria californica
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

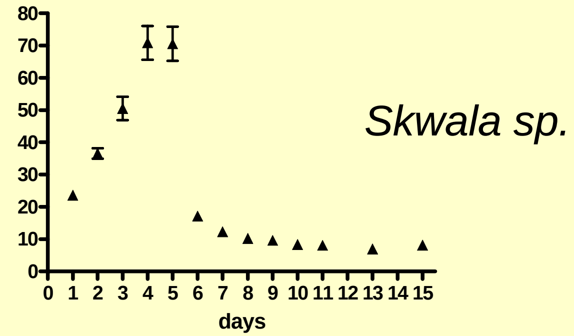


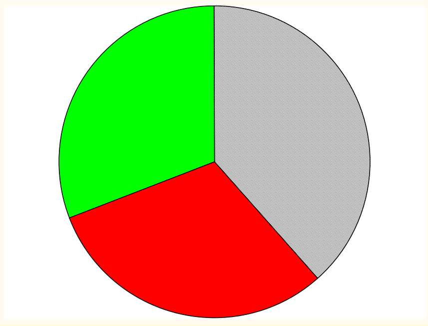

Hesperoperla pacifica
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

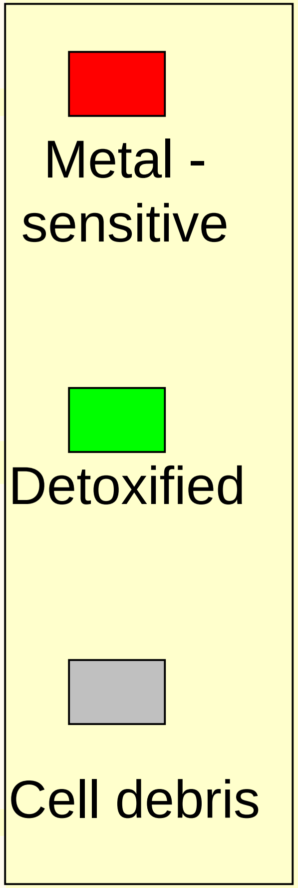



Doroneuria baumani
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

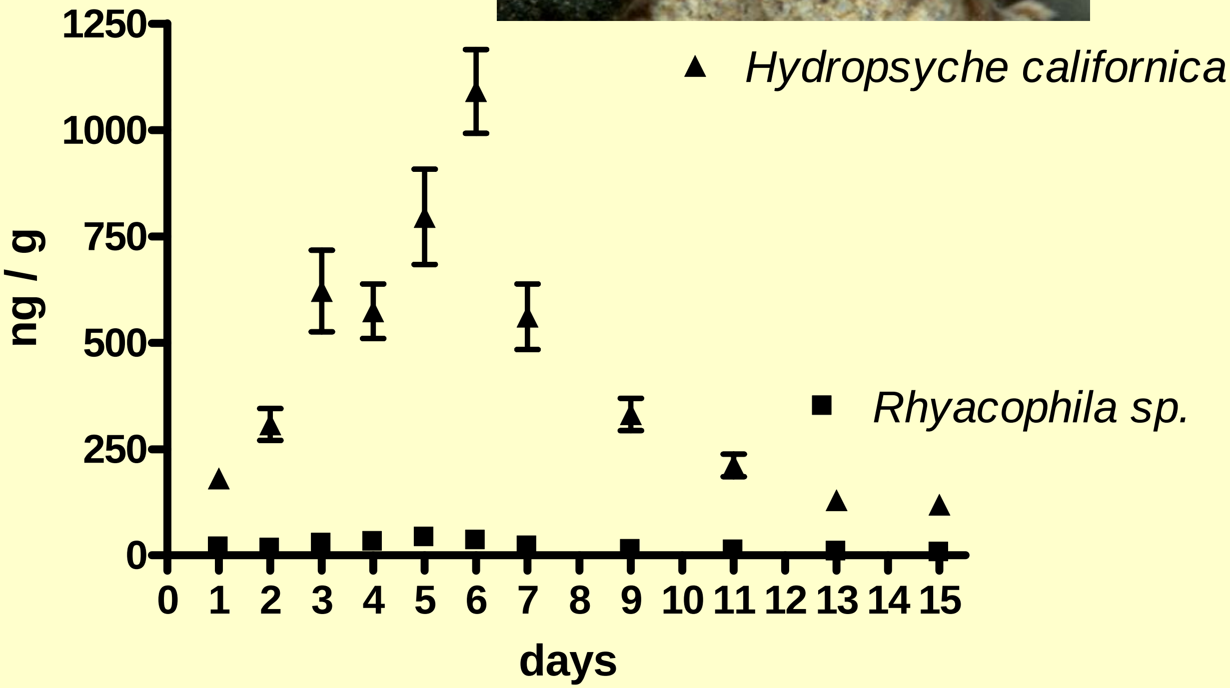


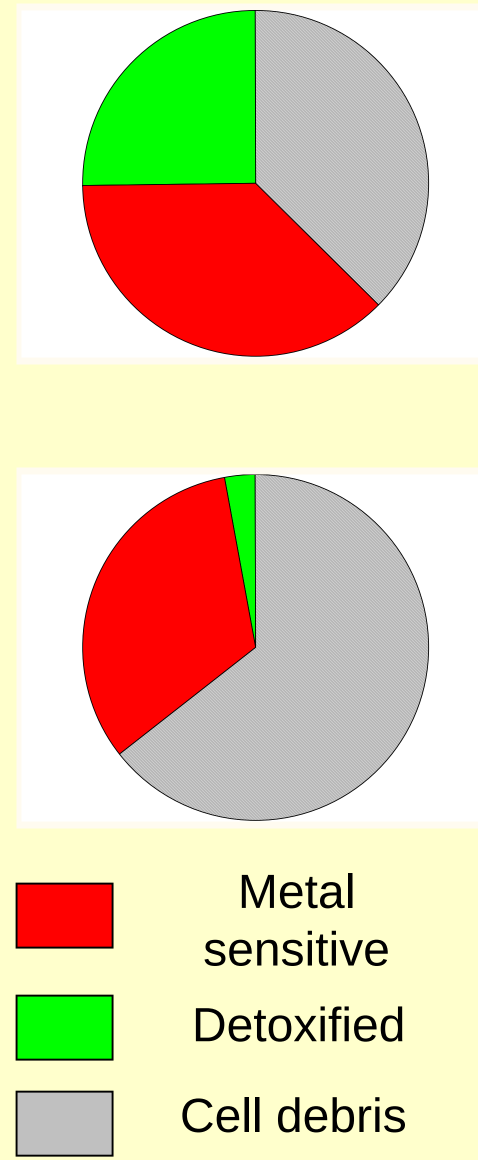

Skwala sp.
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
days



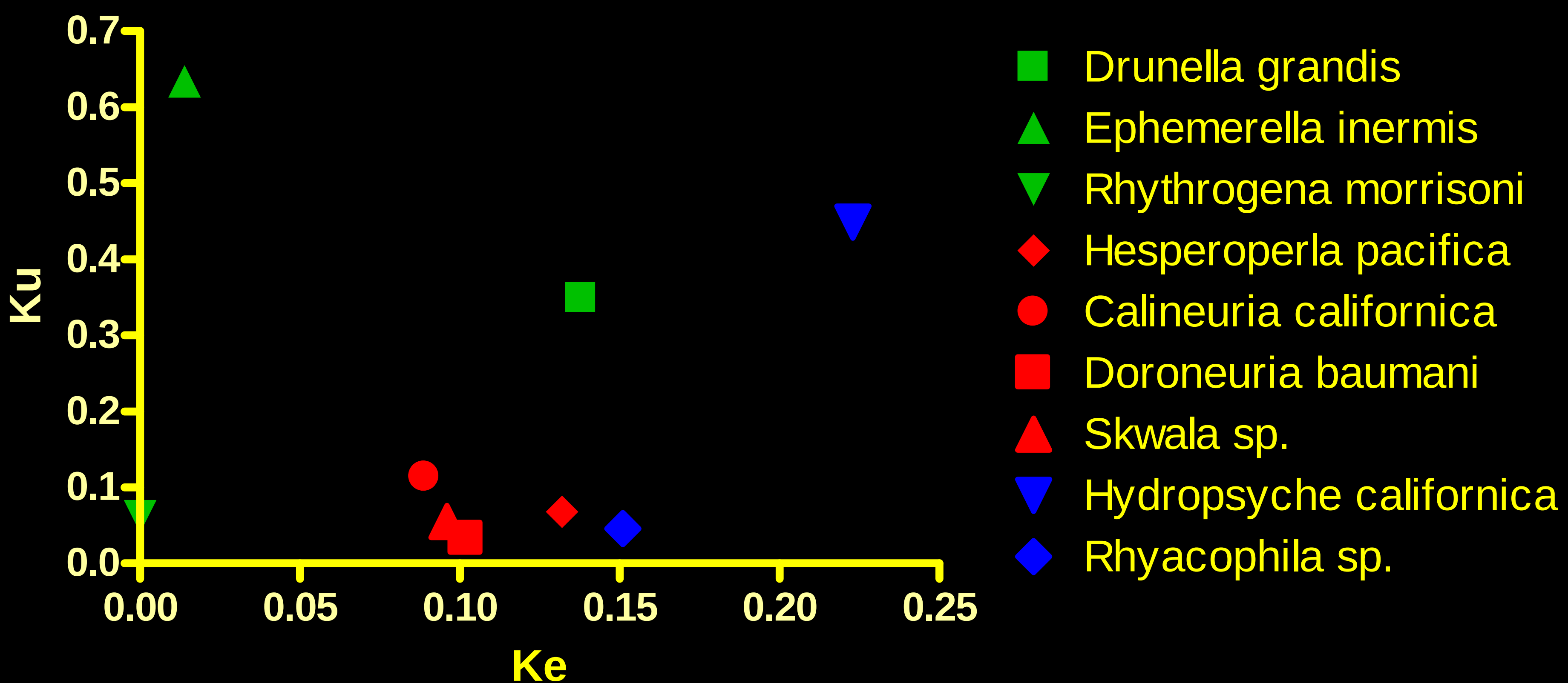

Metal - sensitive
Detoxified
Cell debris

Trichoptera

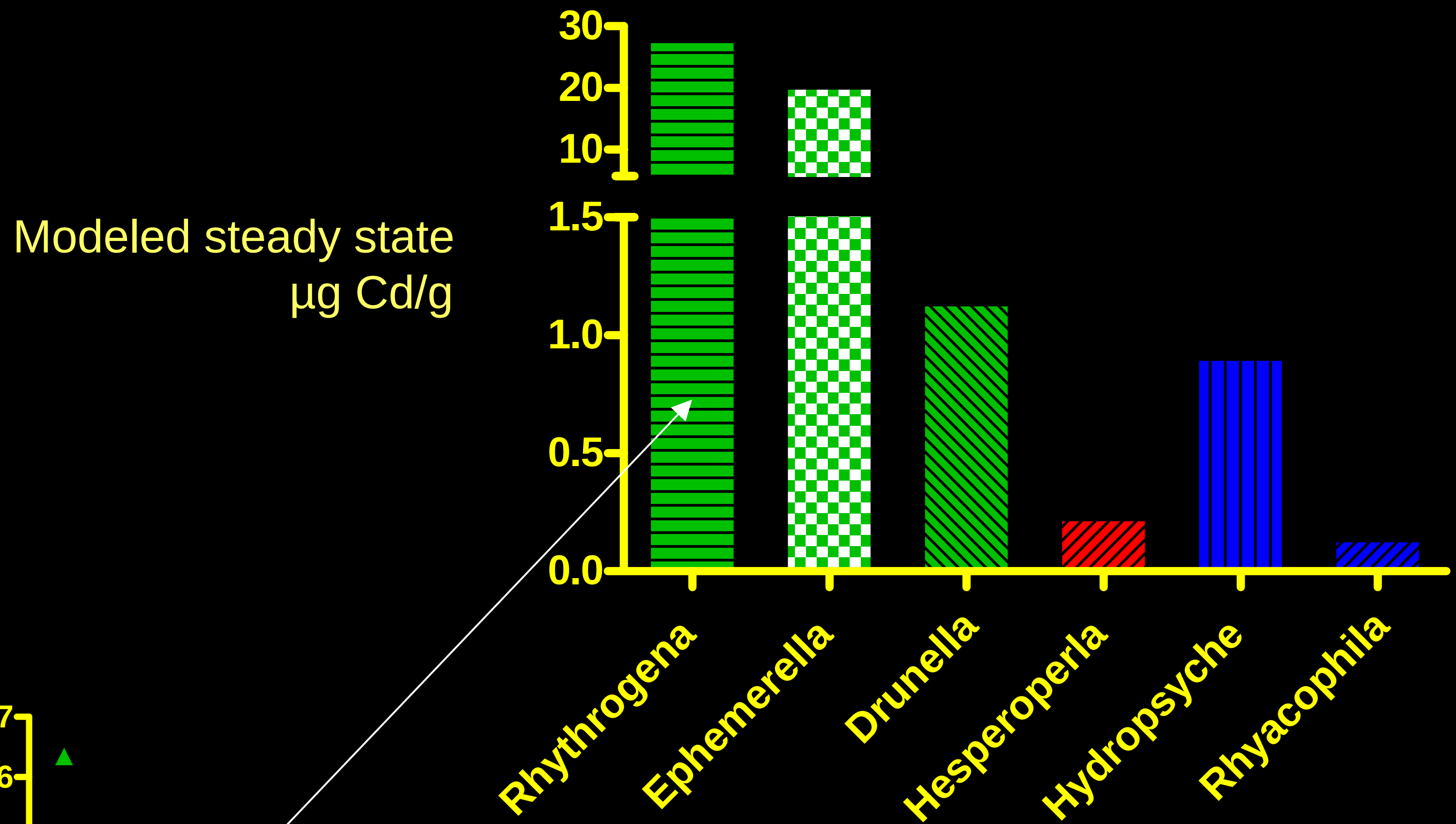


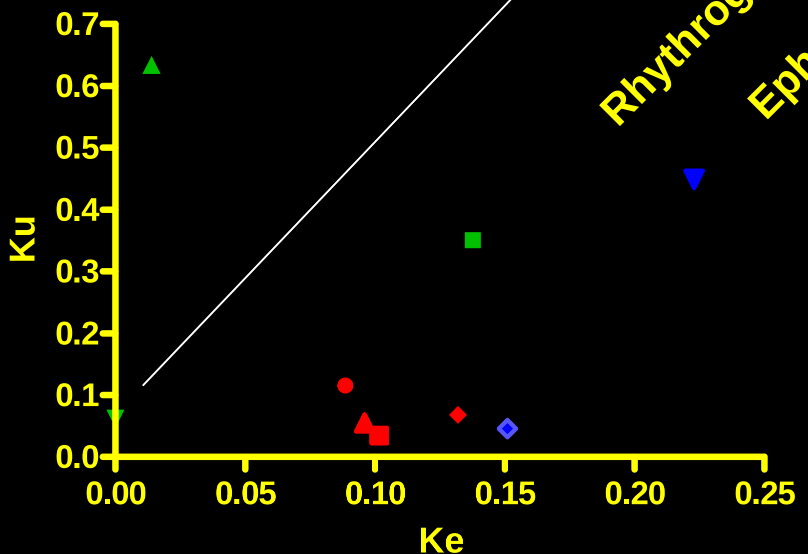


There is no relationship between Ku and Ke values



Rate constants provide steady state [Cd] estimates

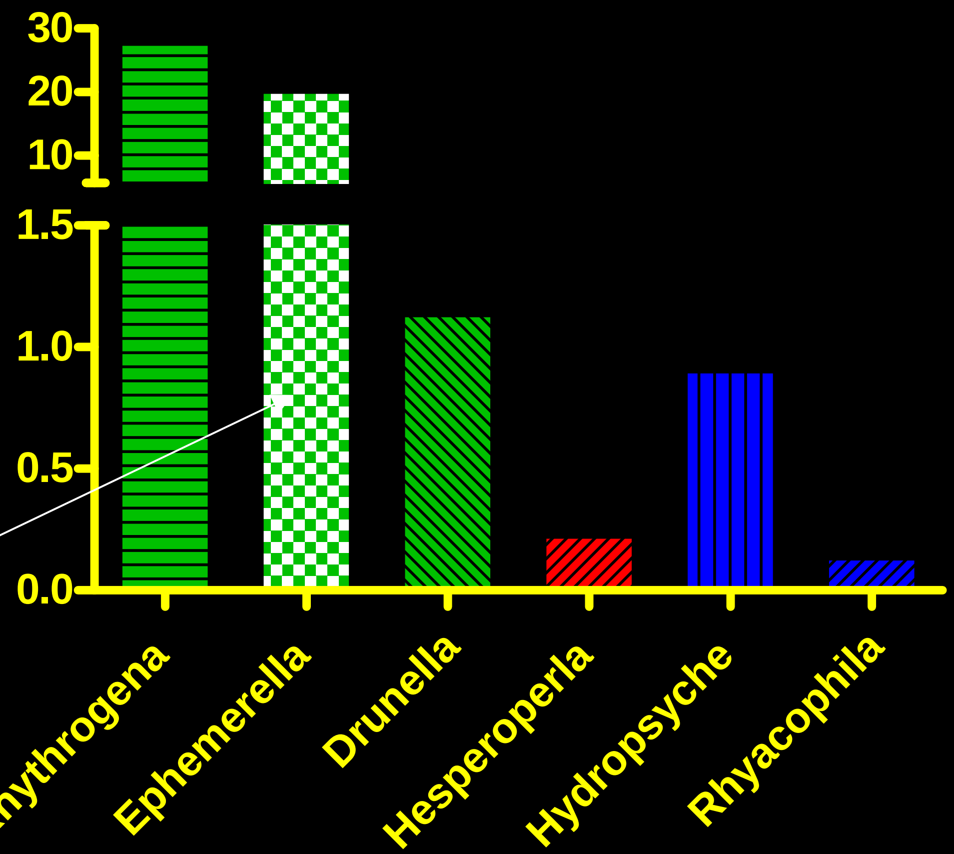


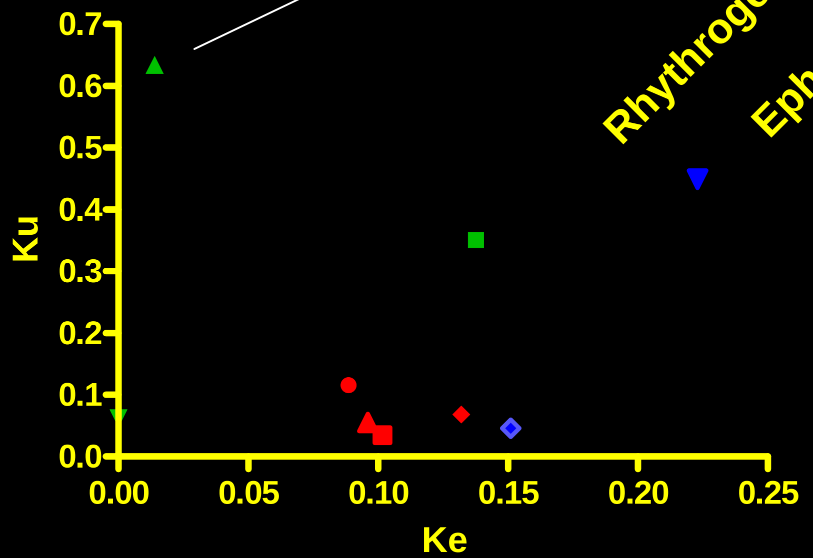


For *Rhythrogena*, very low Ke results in high (lethal?) steady state concentration, despite a low Ku.

Rate constants provide steady state [Cd] estimates

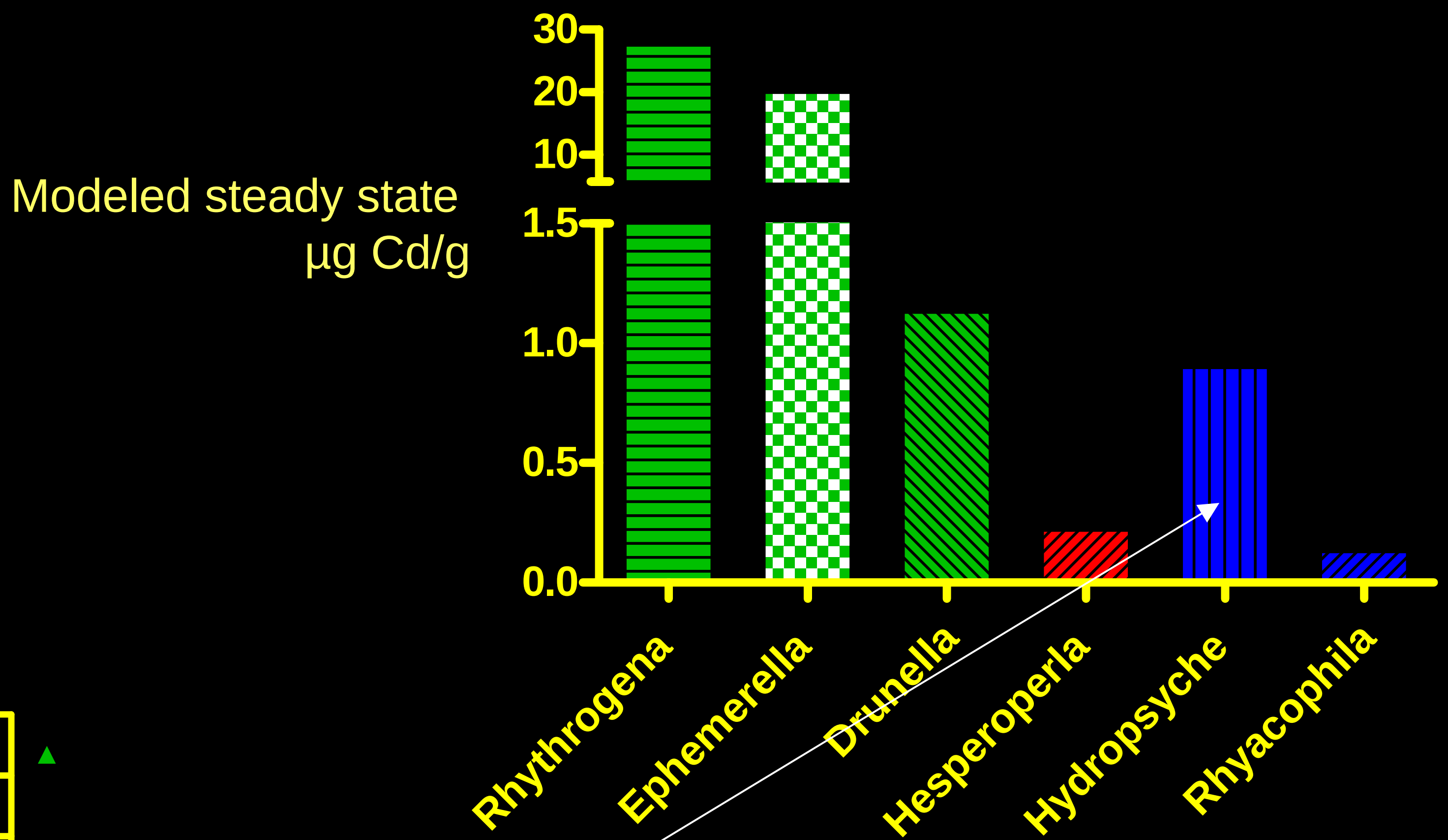
Modeled steady state
µg Cd/g

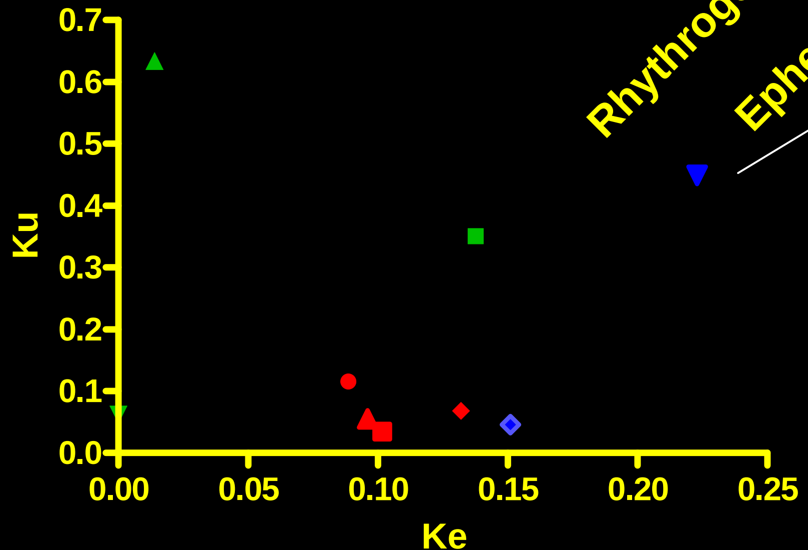




For *Ephemerella*, a high Ku and low Ke result in very high (lethal?) Cd concentrations

Rate constants provide steady state [Cd] estimates





For *Hydropsyche*, a high Ku is offset by a high Ke….so they maintain a moderately low body burden.

Species	Modelled steady state [Cd] (ug / g)	Proportion of Cd in metal sensitive fractions	Steady state [Cd] in sensitive fractions	
Ephemerella inermis	20.37	.49	9.98	
Rhythrogena morrisoni	27.96	.16	4.47	
Drunella grandis	1.14	.51	0.58	
Hydropsyche californica	0.91	.37	0.34	
Calineuria californica	0.57	.41	0.23	
Hesperoperla pacifica	0.23	.50	0.12	
Skwala sp.	0.26	.31	0.08	
Doroneuria baumanni	0.15	.43	0.06	
Rhyacophila sp	0.14	.33	0.05	

Species accumulate very different concentrations of Cd in whole body burdens and in potentially sensitive sites.

Caveats & poster plugs

Cain et al. PT 144

Buchwalter et al. PH 151

Conclusions

- Influx, efflux and subcellular fractionation vary considerably among species
- By combining these physiological parameters, it is possible to infer Cd vulnerability differences (from dissolved exposures) among species


buchwalt@usgs.gov