Development of a mayfly model (*Centroptilum triangulifer*) for ecotoxicology and bioaccumulation studies: Selenium trials

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Aquatic insects are under-represented in ecotoxicology

- 70-90% of the invertebrate species pool in most lotic systems
- Ecologically important
- Extensively used as ecological indicators

- Typically difficult to culture
- Complex life cycles, dietary requirements
- Flow

What about *Chironomous*?

- Too tolerant
- Sediment associated

Introducing: *C. triangulifer*

- Native to the Eastern US and Canada
- Only lives in rivers, but prefers marginal habitats
- Parthenogenic
- Imago lays eggs (~1000) upon wetting
- Eggs can be stored at 4°C

Life cycle

Temperature °C	Days to adulthood
25	27
20	45
10	179

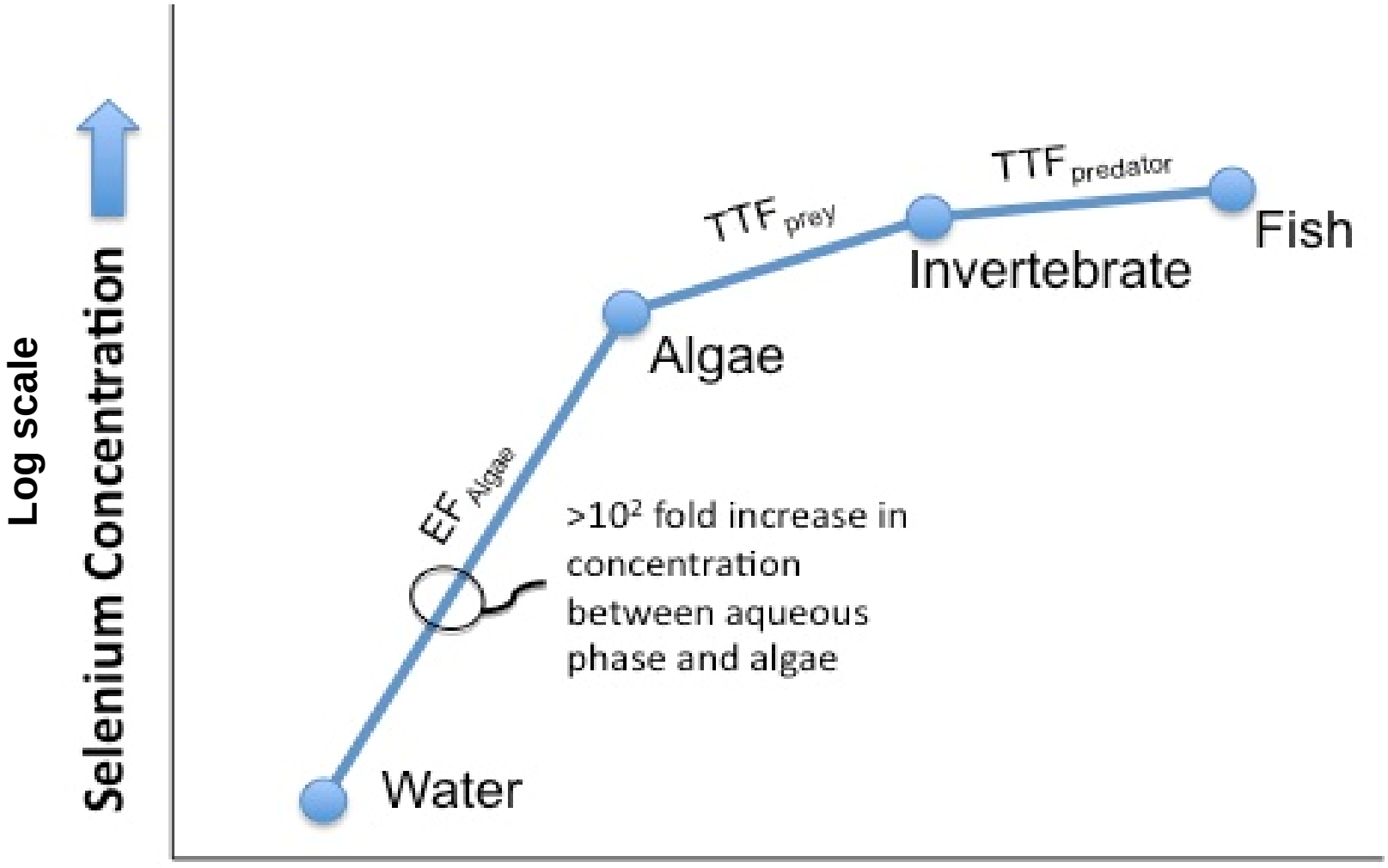
Source: Sweeney and Vannote, 1984 *Freshwater Biology*

Diet: diatoms

Since the biggest “jump” in bioaccumulation of most metals/metalloids in food webs occurs at the incorporation stage (primary producers), trophic transfer from the base of food webs is central to understanding exposure and effects

A culturable mayfly that grazes on periphyton and diatoms is a more environmentally relevant test species for streams and rivers than Daphnids or other common “lab rats”

Selenium movement through food webs: Insights from marine studies



Selenium 101

- Selenium is an essential element with a narrow window between essentiality and toxicity
- Kesterson, Belews lake and other areas of intense Se contamination show population crashes and teratogenicity (birth defects) in fish and birds
- Bioaccumulation of Se in aquatic systems is primarily thought to be via diet.

Selenium

- Surprisingly little work done in stream systems
- Conventional wisdom is that insects are simply conduits of Se to higher trophic level organisms (fish and birds)
- Limited evidence that invertebrates are affected by Se (but see Debruyn and Chapman, 2007 ES&T)

Diet

Experimental design

1.8 L water (ASTM artificial soft water)

Controls

5 µg/L

10 µg/L

20 µg/L

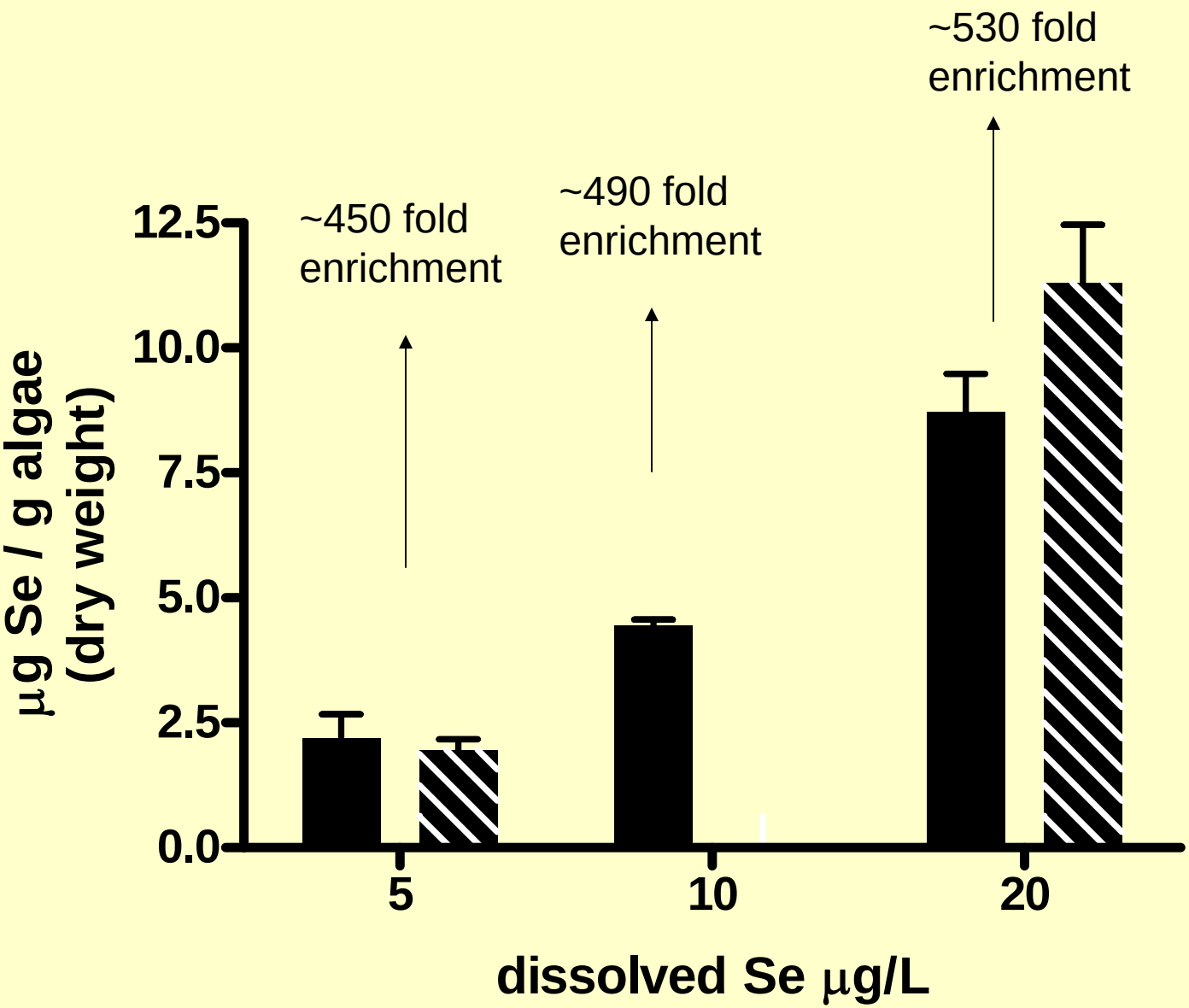
^{75}Se as selenite added as a tracer

This allowed us to quantify Se in water and in periphyton scrapings over time

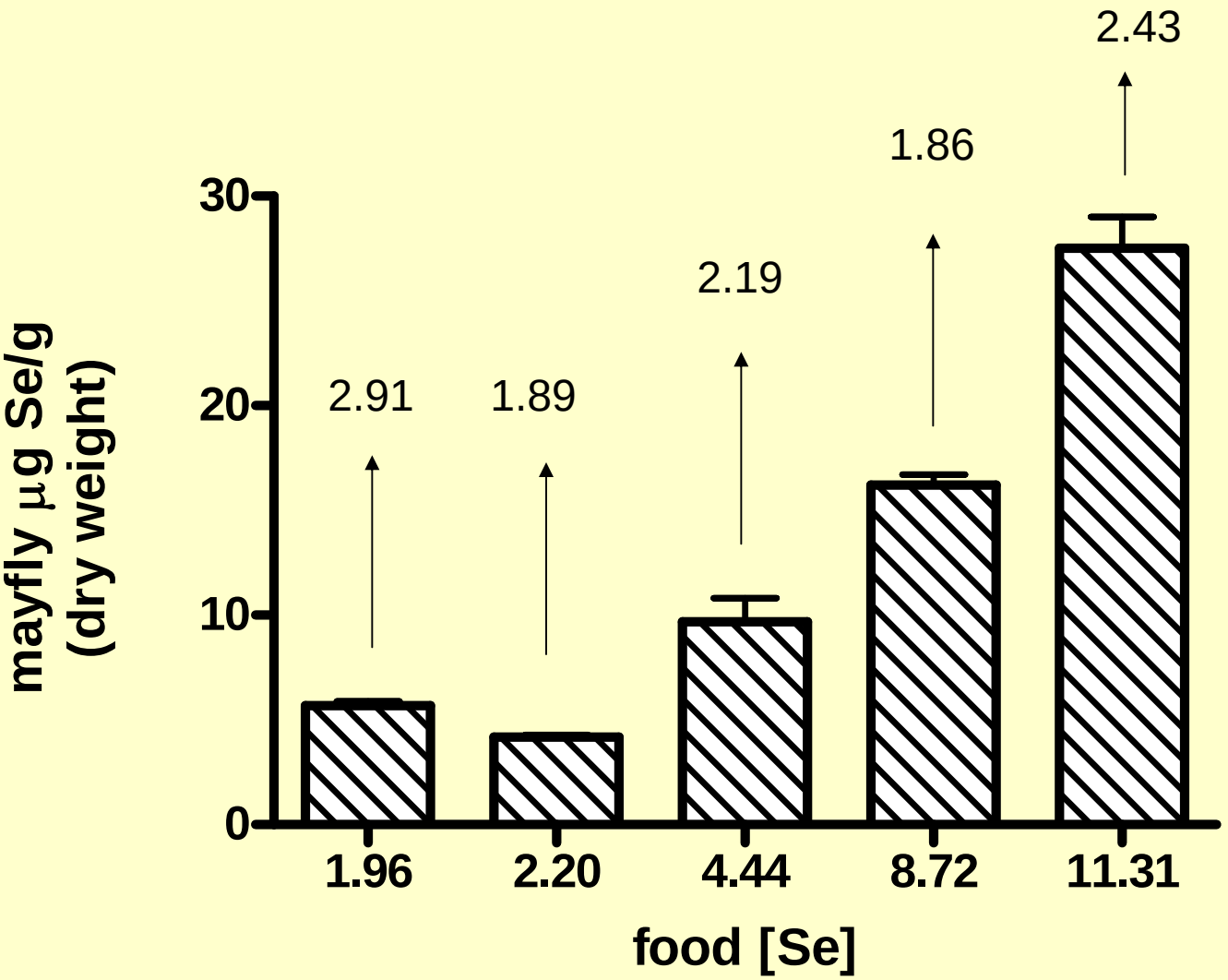
Algal plates exposed for 1 week prior to transfer to clean water

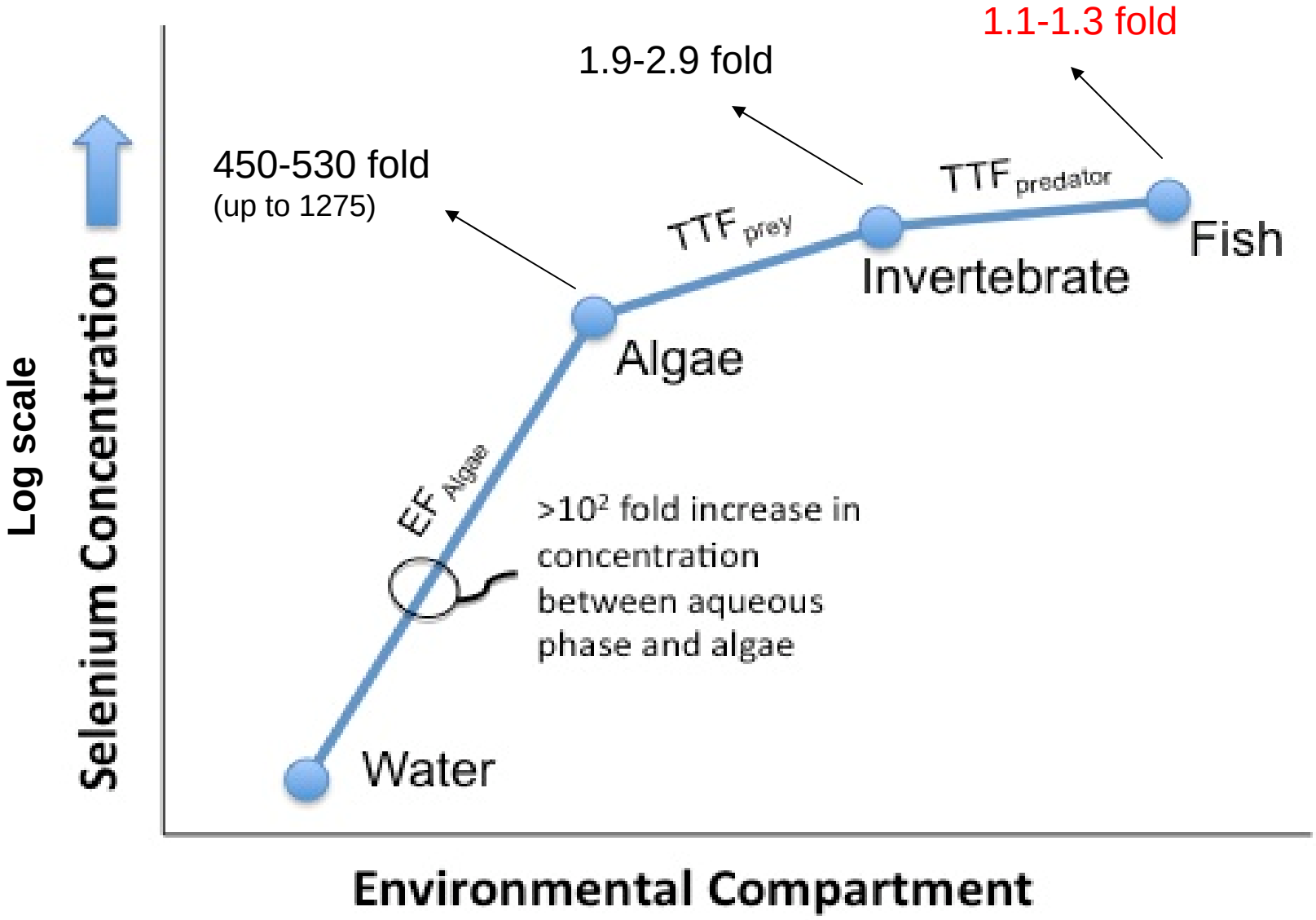
20 *Centroptilum* larvae (7 days old) added to each bottle

Concentration of Se by algae



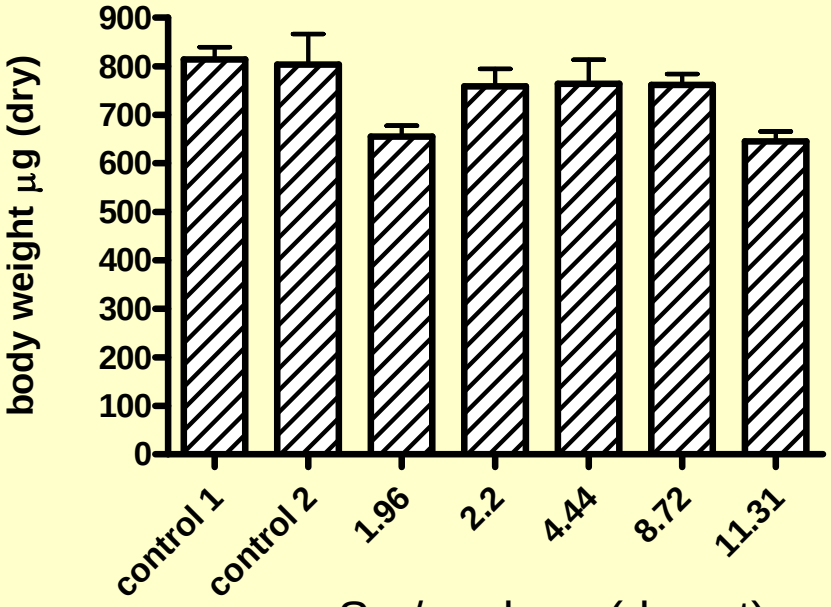
Trophic transfer of Se from periphyton to mayfly adults (after laying eggs)




1.1-1.3 fold
1.9-2.9 fold
450-530 fold
(up to 1275)
TTF predator
TTF prey
Fish
Invertebrate
Algae
EF Algae
>10² fold increase in concentration between aqueous phase and algae
Water
Log scale
Selenium Concentration
Environmental Compartment

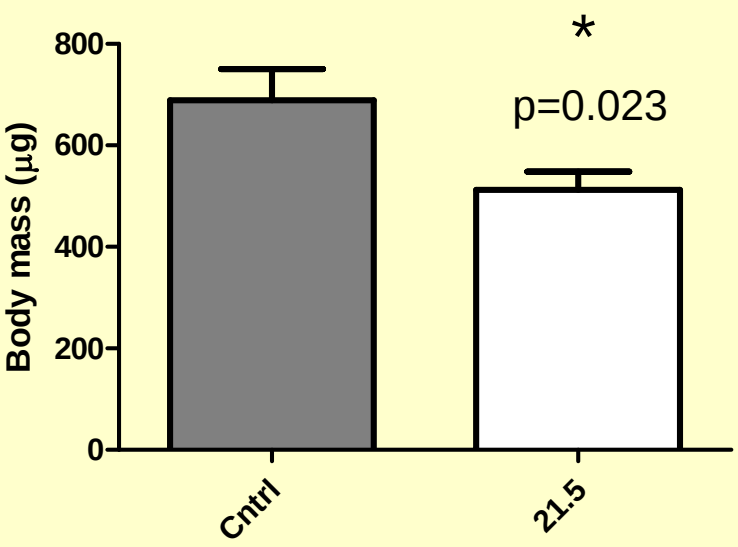
Effects of dietary Se on mayflies?

Dietary Se in this range does not appear to affect growth



µg Se / g algae (dry wt)

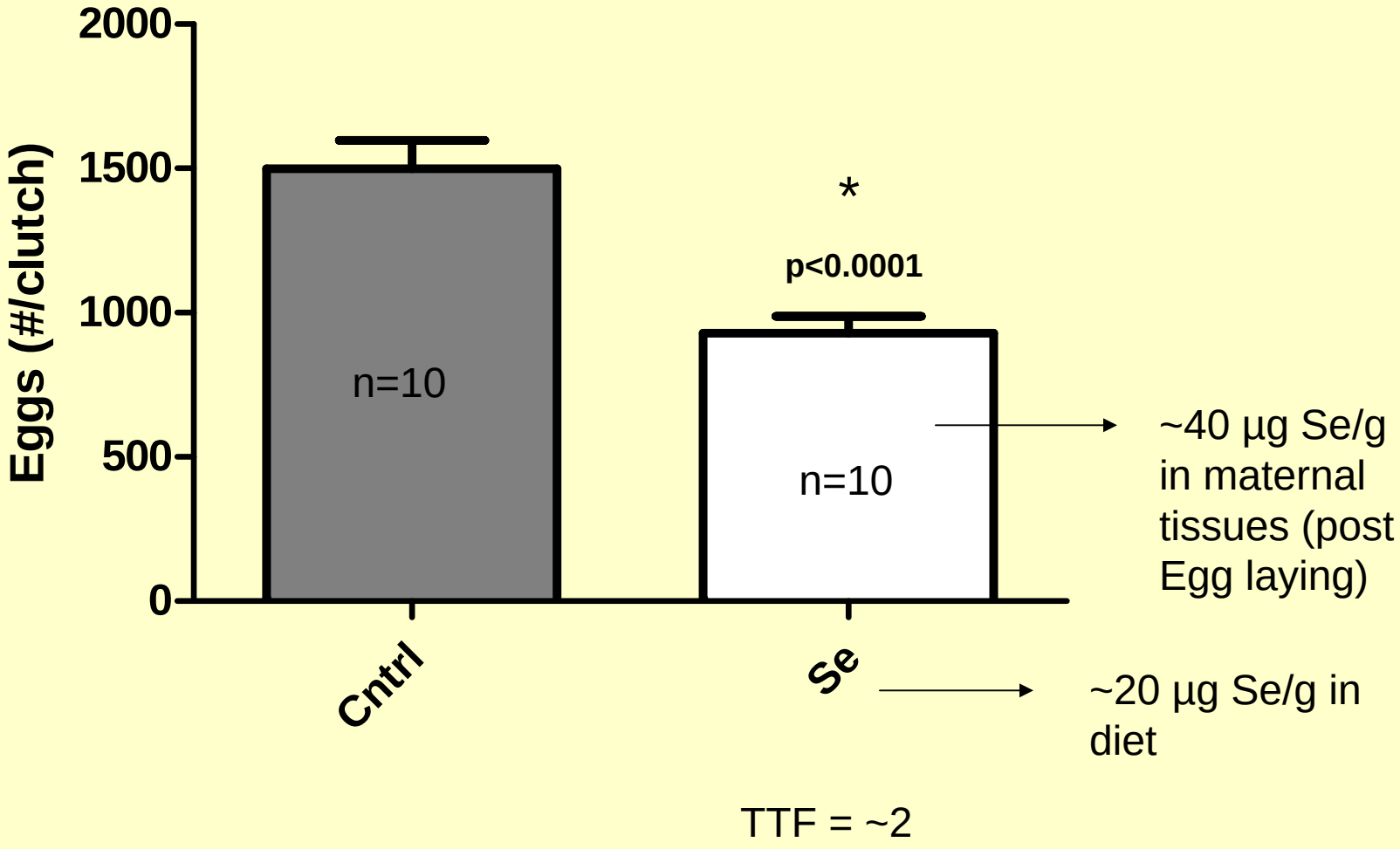
At higher dietary Se, growth is affected



µg Se / g algae (dry wt)

Note that these experiments were run with different batches of algal plates. Food quality/algal species differences are important.

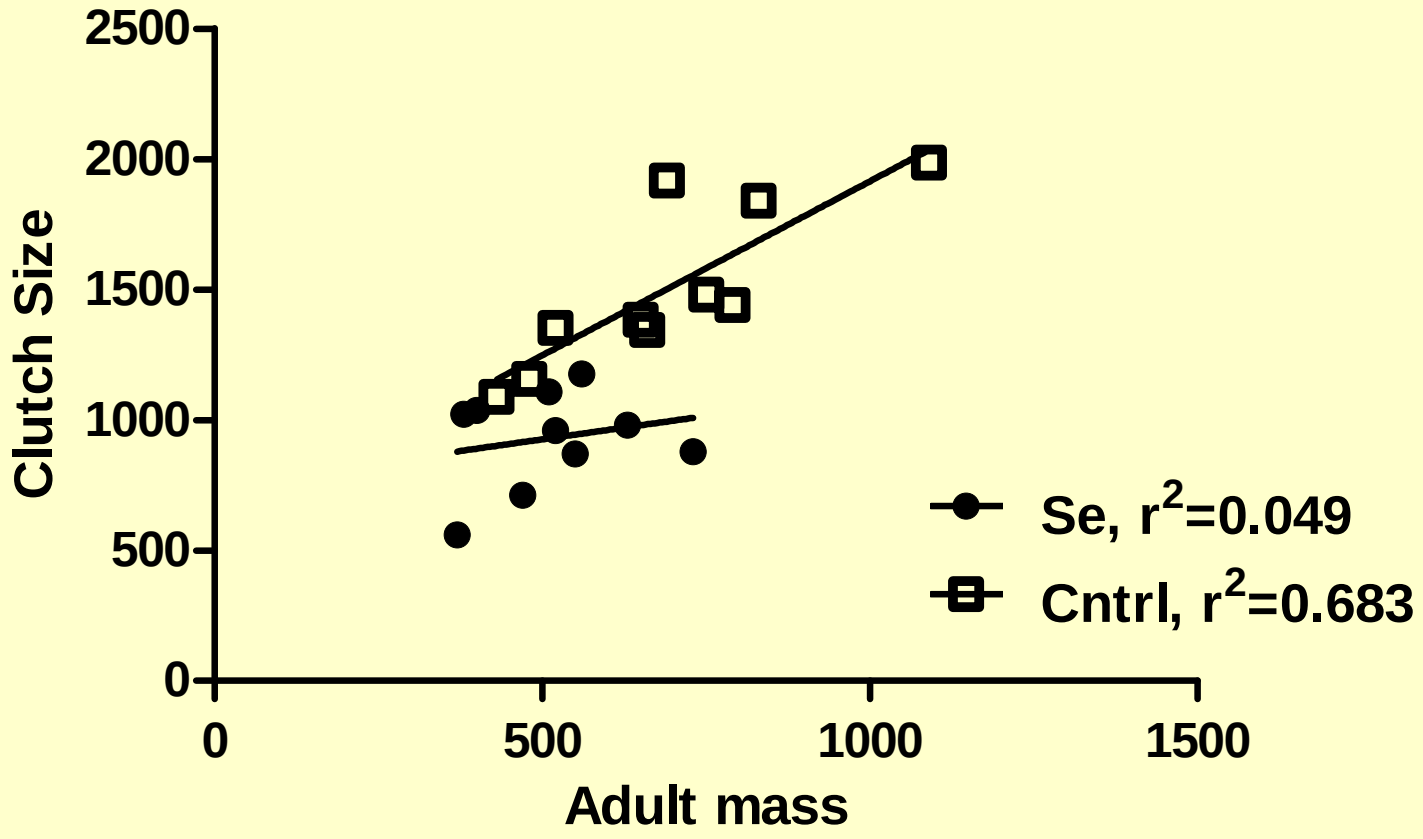
At higher maternal selenium concentrations, fecundity is affected



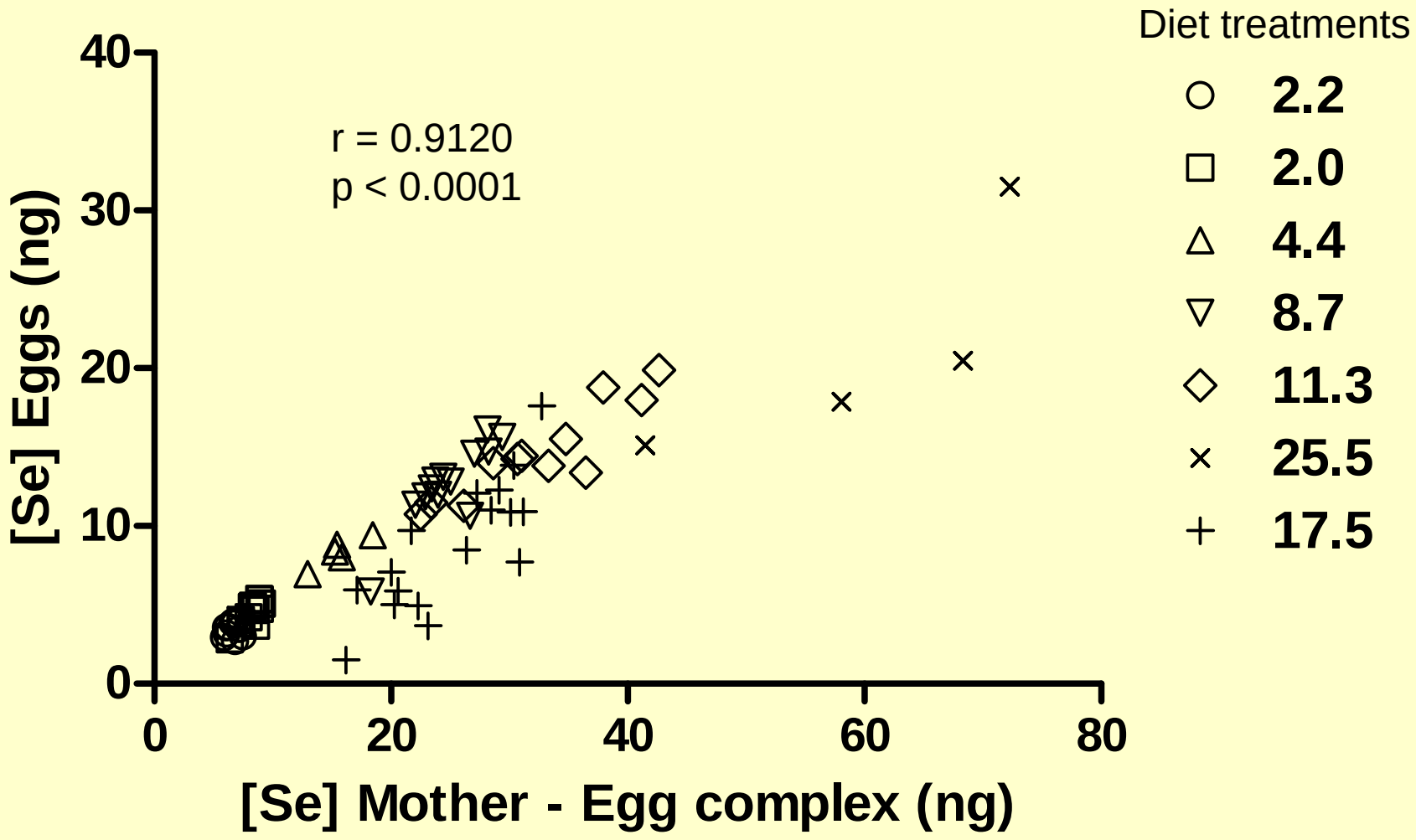
TTF = ~2

At high maternal Se concentration, growth is stunted, and fecundity is affected

but reduction of fecundity is not directly tied to reduced growth



Maternal transfer of Se to eggs is consistent across all maternal Se body burdens/dietary treatments



What does it all mean?

- The general paradigm of Se movement through food webs that has been established for marine systems seems to hold for freshwater environments
- Contrary to conventional wisdom, insects can be affected by high selenium content in their diets
- Given the importance of insects in the diets of fish and birds, it is important to understand their bioaccumulation of Se

Uncertainties and data gaps

- One major difference between fresh and marine systems could relate to inorganic Se forms: selenate uptake into marine algae is quite slow (sulfate competition), whereas selenite uptake is important

- How do primary producers (algae, diatoms) in freshwater vary in their Se bioaccumulation?

- The assumption that dissolved Se uptake is unimportant is not universally true for insects

Future directions

- Development of *Centroptilum* as a model test species
  - TDS work, other elements (Cd, nanoparticles)
  - Need to normalize diet
- Larval Se work with different mayfly grazers
  - Bioaccumulation and antioxidant responses

A model for toxicogenomic studies?

We recently sequenced a cDNA library from animals treated with:

- Cu, Cd, Hg mixture
- hydrogen peroxide
- 20-OH ecdysone
- phenobarbitol
- chlorpyrifos/atrazine mixture
- controls

7,000 contigs

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