



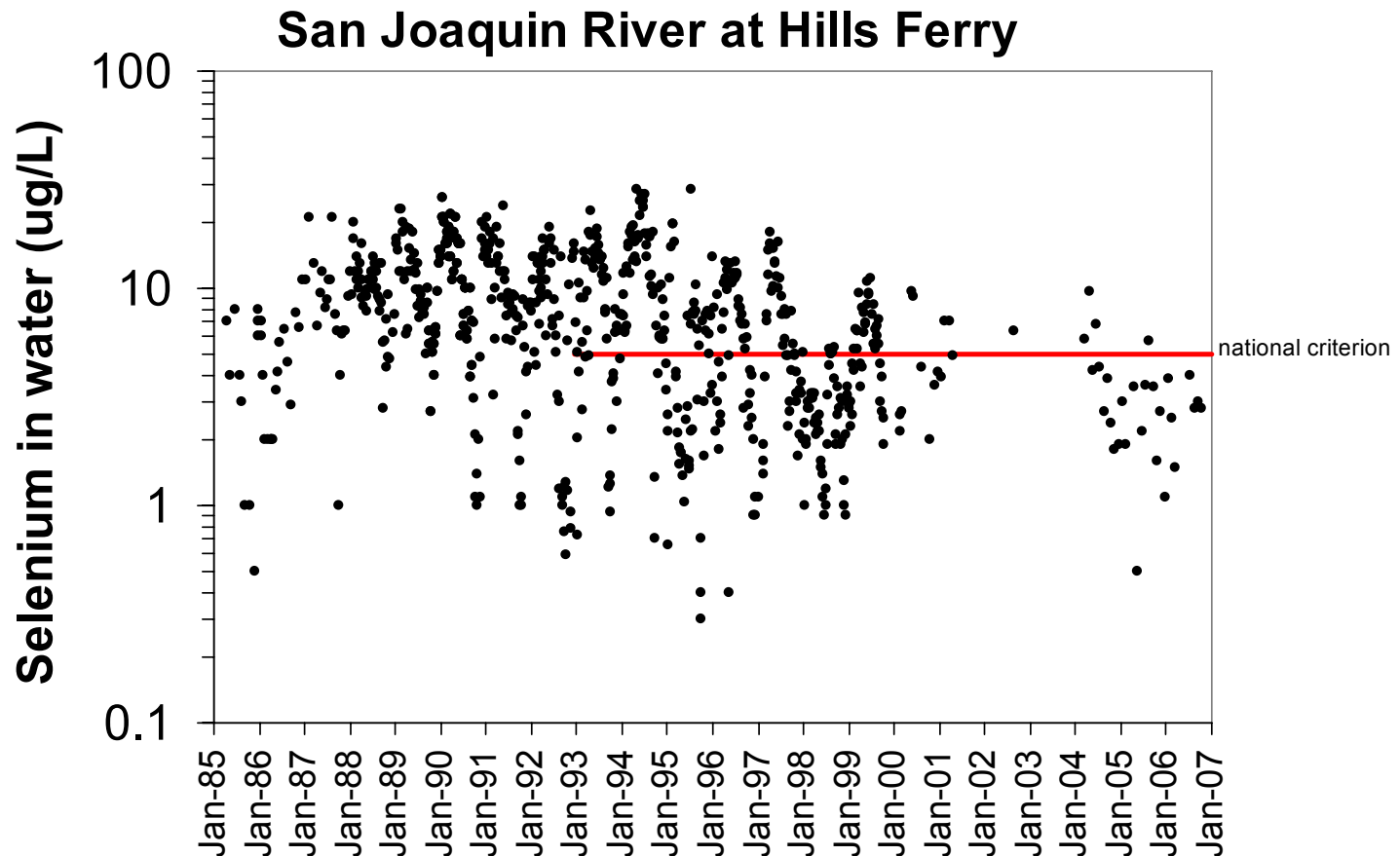
Toxicity of Selenium to Salmonids

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Presented at CalFed Science Conference, Sacramento, CA, October 24, 2008

EPA selenium criterion
“for the protection of aquatic life:”
5 ppb ($\mu\text{g}/\text{L}$) in water
since 1992

Most selenium-contaminated stretch of any major river in the Central Valley:



- Selenium levels have been approaching compliance

Is the 5 ppb national criterion protective of salmonids?

- Selenium in the water has little direct effect on fish.
- Toxicity is due to selenium accumulated in the tissue of fish from selenium in their diet.
- Most directly relevant: relationship of selenium in tissues to adverse effects.

Chronic Fish tissue-based criterion

United States
Environmental Protection
Agency

Office of Water
4304

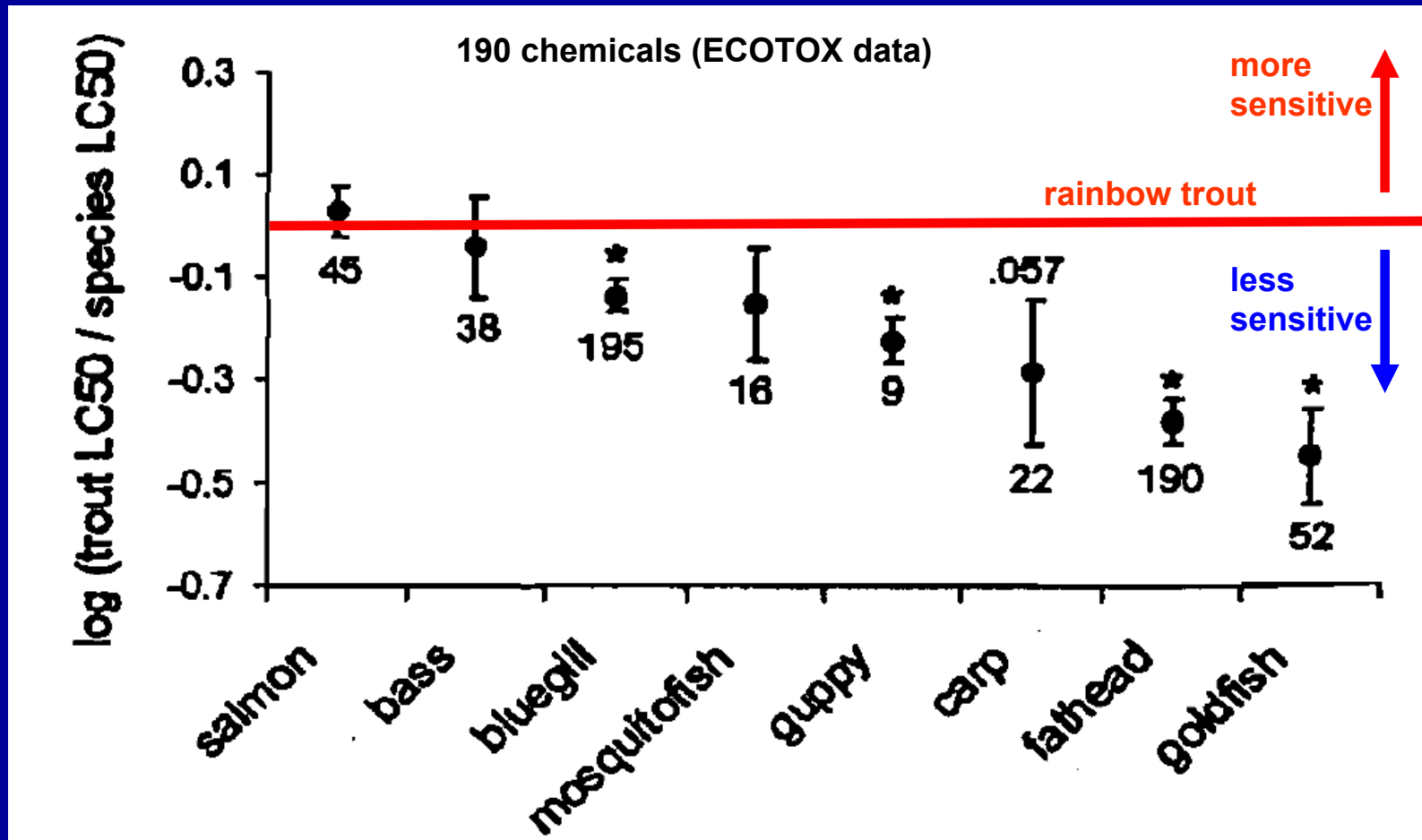
EPA-822-D-04-001
November 2004



Draft Aquatic Life Water Quality Criteria for Selenium - 2004

- 7.91 $\mu\text{g/g}$ (whole body, dry weight)
- LOAEC for juvenile mortality at 4° C.
- Bluegill sunfish (Lemly 1993), a “warmwater fish”

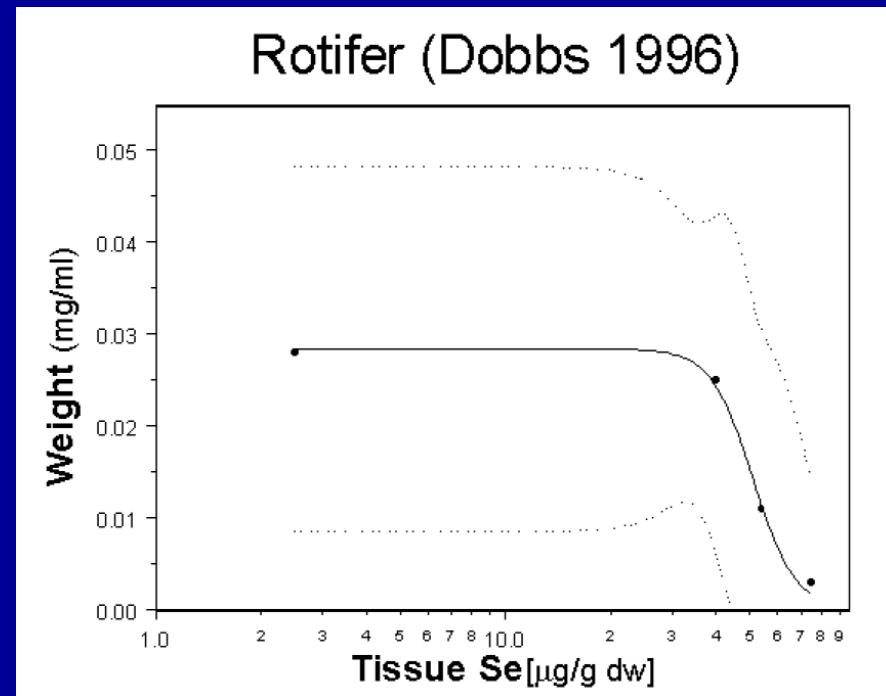
Aren't coldwater fish (salmonids) more sensitive?



Did EPA miss something?

- Data selection
- Model used for regression (monotonic)
- Criterion effect level (20%)
 - If it kills 1/5 of the population, is it protective?

Included in analysis:



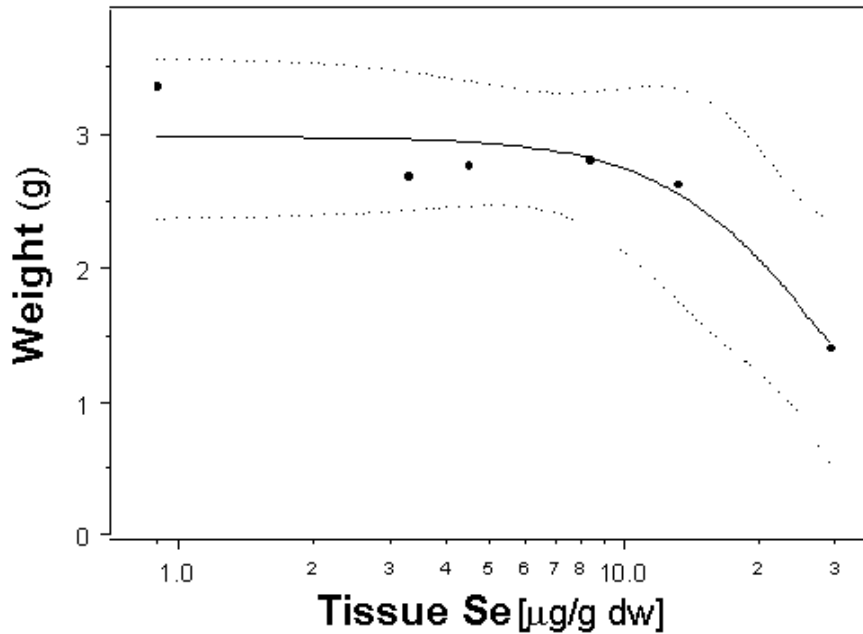
From EPA 2004

Included:

selenium effect on salmon growth -- 60 days

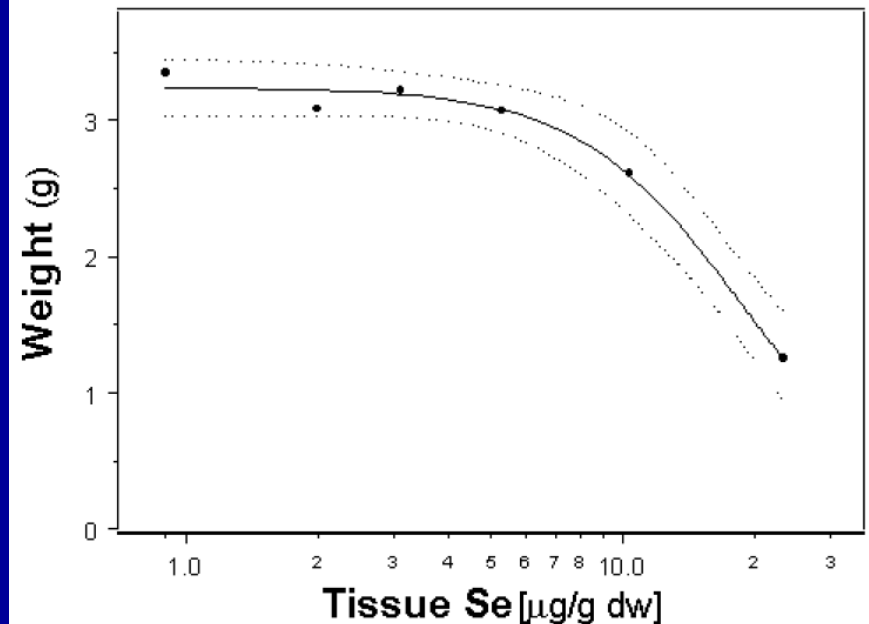
Chinook Salmon

SLD Diet - 60 Days (Hamilton et al.1990)



Chinook Salmon

SeMet Diet - 60 Days (Hamilton et al. 1990)



EC20 = 15.74 $\mu\text{g/g}$ dry wt.

EC20 = 10.47 $\mu\text{g/g}$ dry wt.

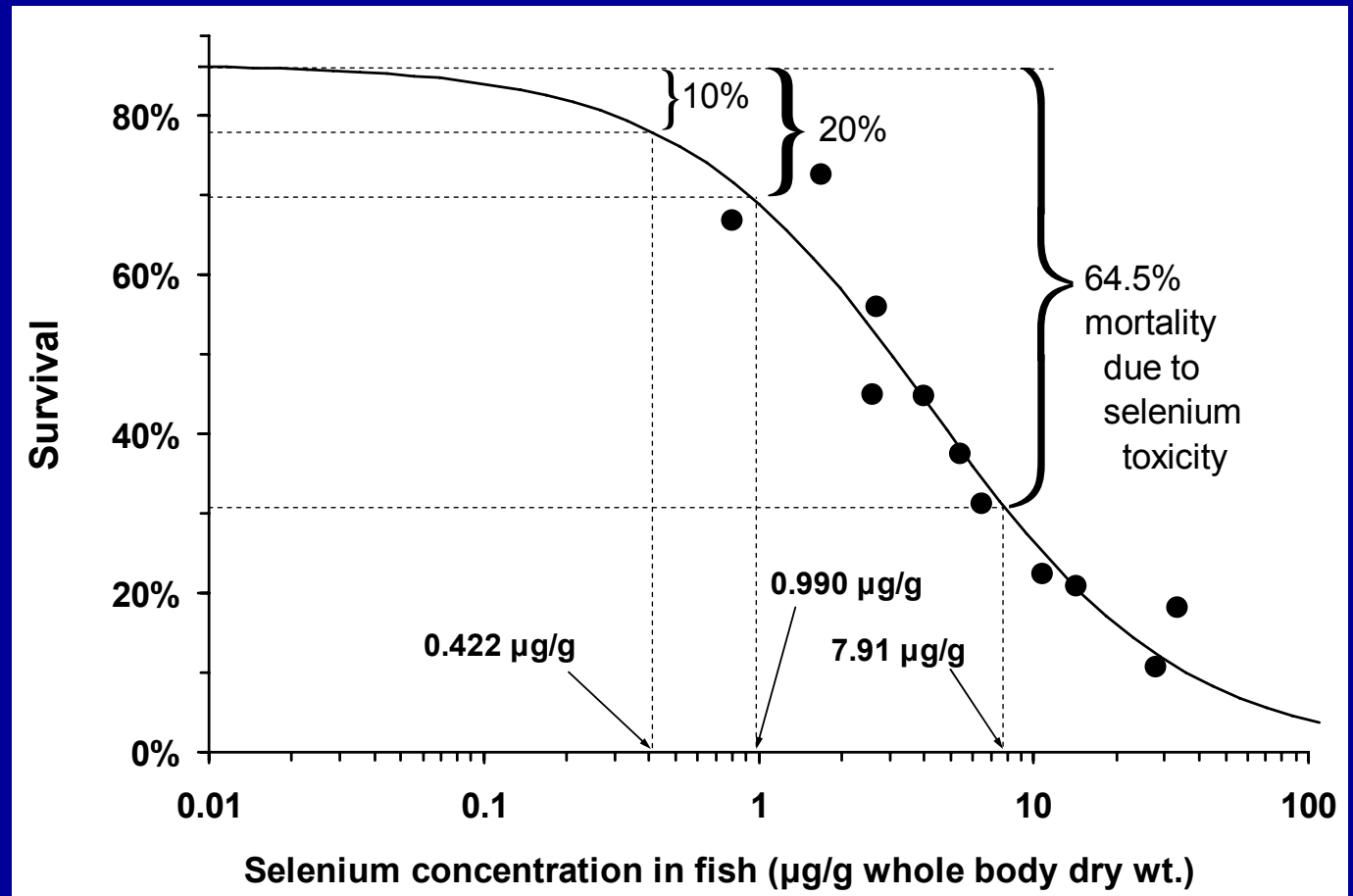
Species Mean Chronic Value:

SMCV = 12.84 $\mu\text{g/g}$ dry wt.

Excluded:

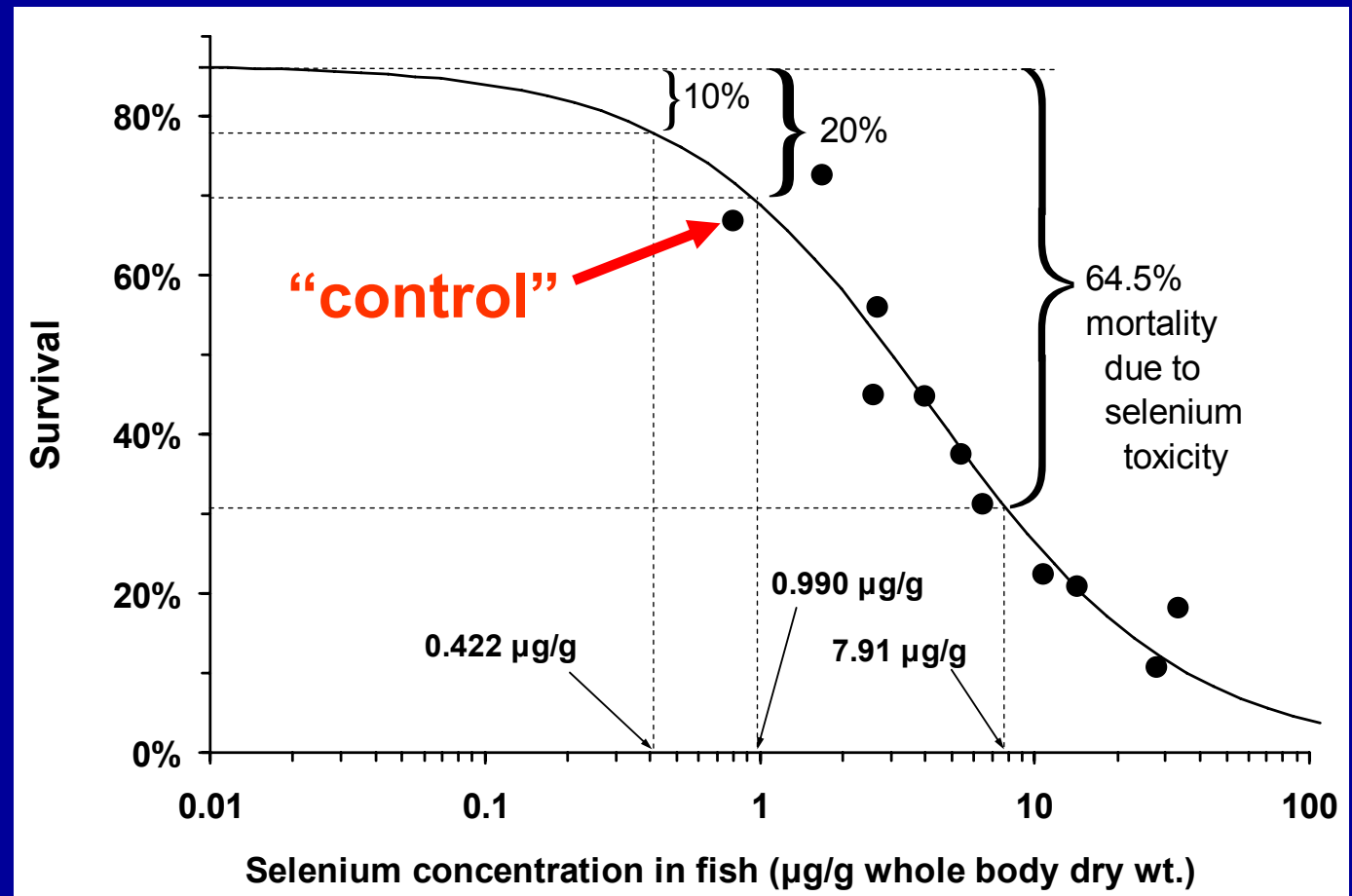
selenium effect on salmon survival -- 90 days
same study

- Larval Chinook salmon from the Merced fish hatchery.
- Exposed to dietary selenium for 90 days.
- Log-logistic model.

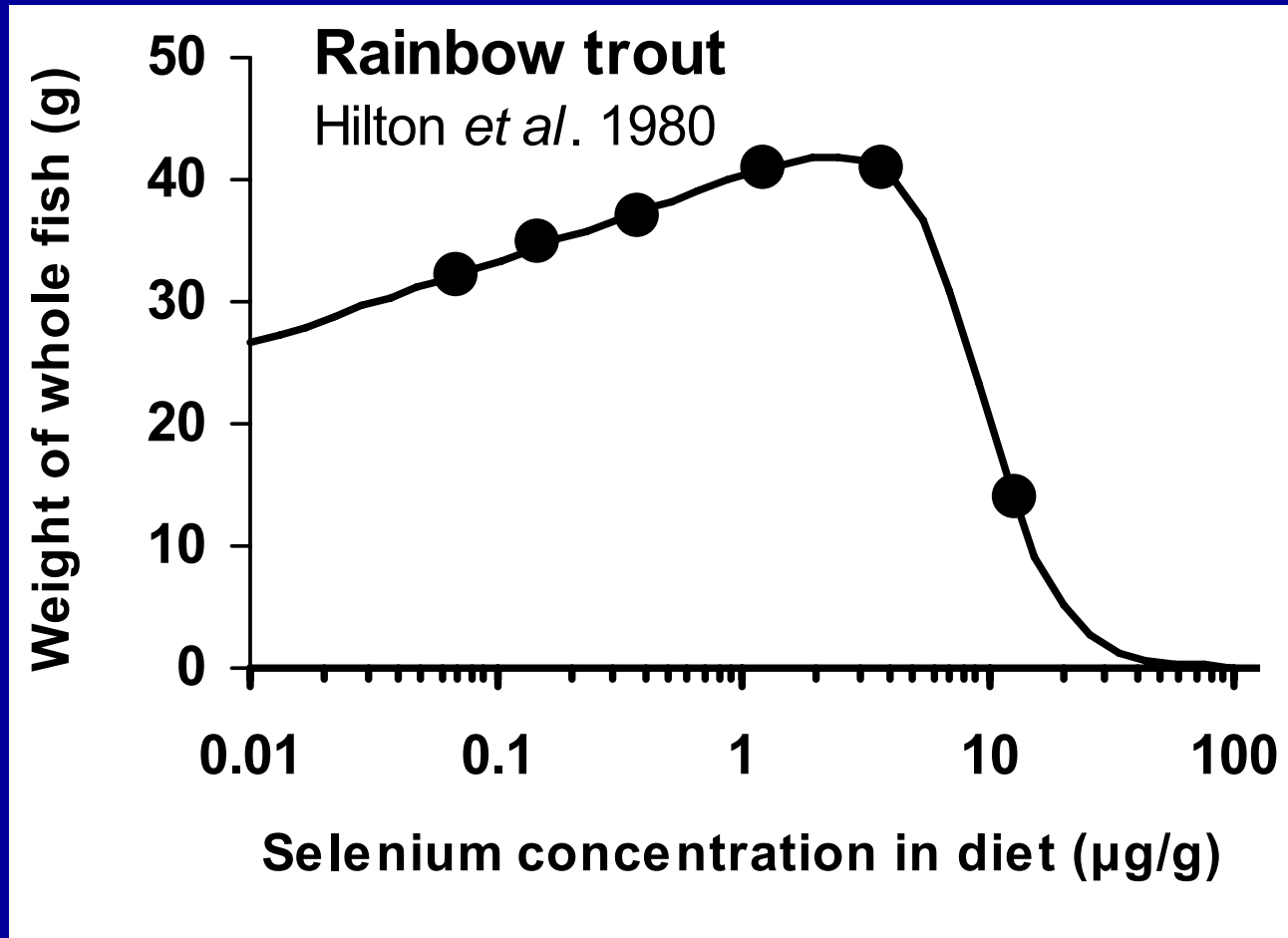


Stated reason for exclusion : “unacceptable control mortality” 60 - 90 days

- But the “control” was in line with other treatments



Selenium is essential as well as toxic...
so regression model should be biphasic



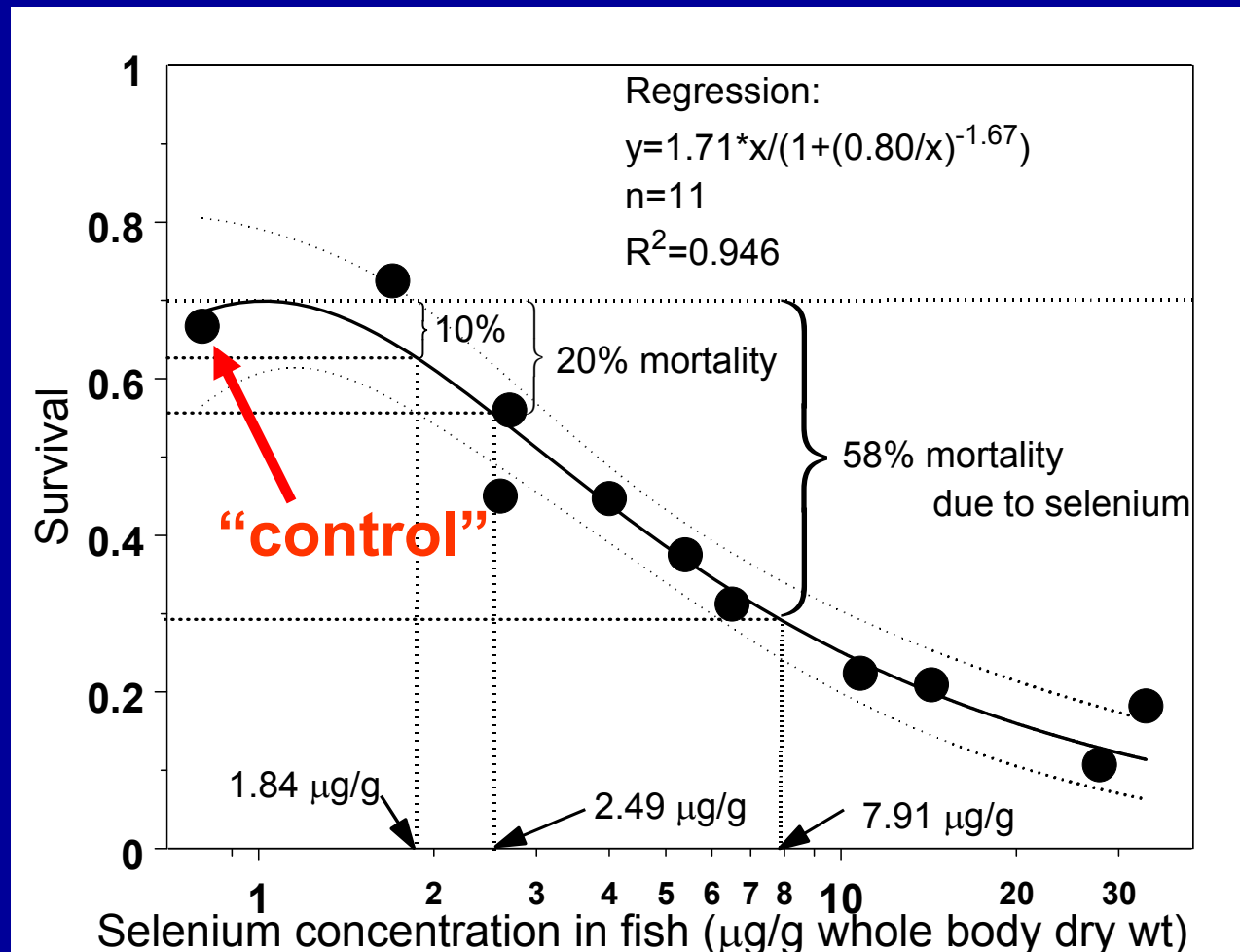
Data: Hilton JW, Hodson PV, Slinger SJ. 1980. The requirement and toxicity of selenium in rainbow trout (*Salmo gairdneri*). *J Nutr* 110:2527-2535.

Regression: Beckon WN, Parkins C, Maximovich A, Beckon AV. 2008. A general approach to modeling biphasic relationships. *Environ Sci Technol* 42:1308-1314.

Biphasic model

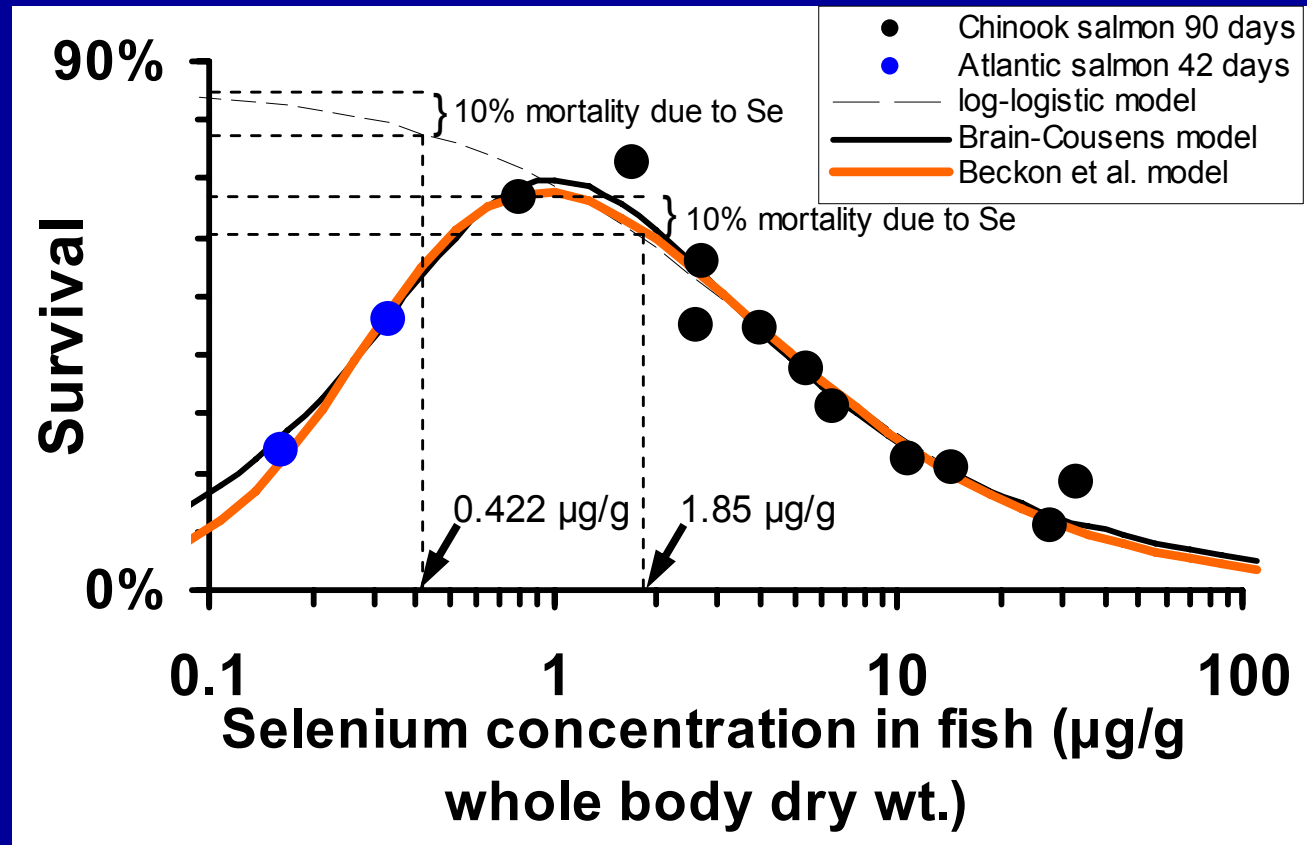
applied to Hamilton *et al.* 1990

- “Control” is in good agreement with other data
- Optimum [Se]: about 1 µg/g
- LC10 = 1.84 µg/g



Better biphasic model: same result

- Model of Beckon *et al.* (2008)* is more flexible but requires deficiency data.
- Additional data from Atlantic salmon†



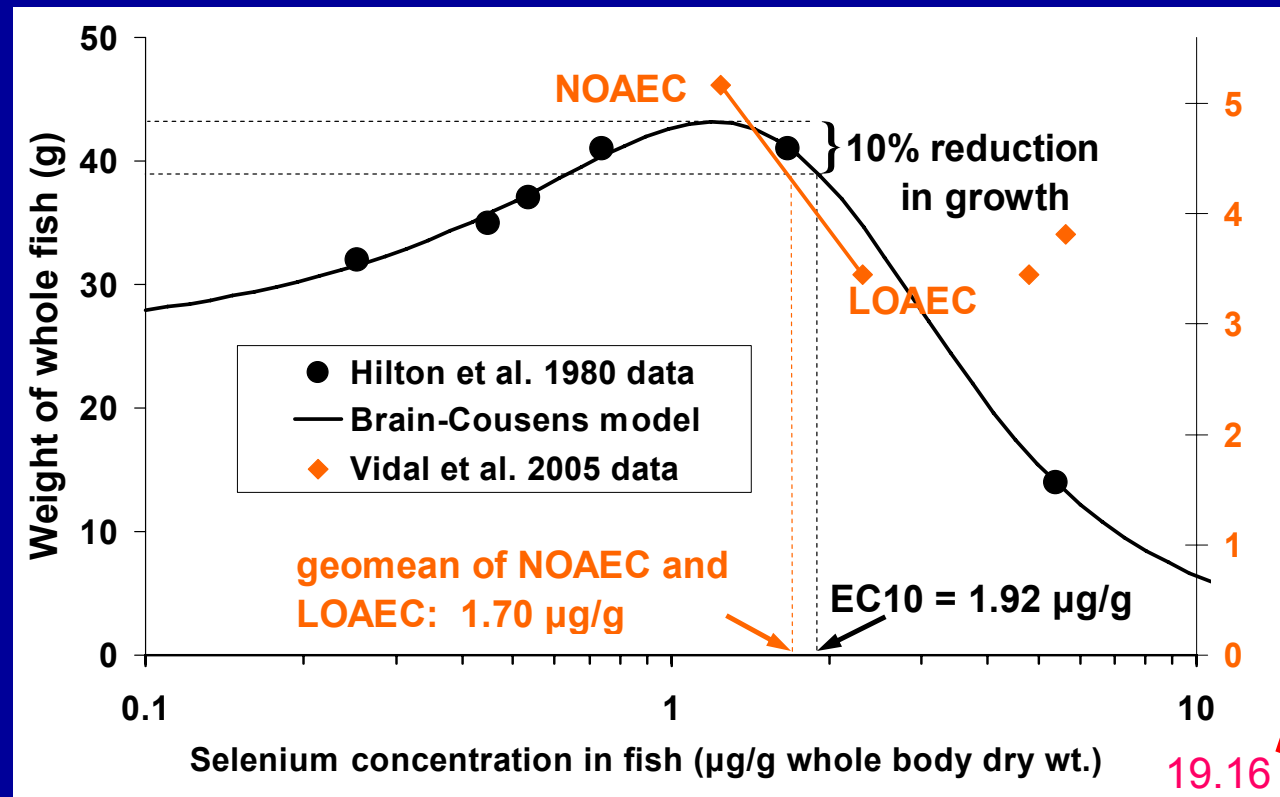
*Beckon WN, Parkins C, Maximovich A, Beckon AV. 2008. A general approach to modeling biphasic relationships. *Environ Sci Technol* 42:1308-1314.

† Poston HA, Combs GF, Leibovitz L. 1976. Vitamin E and selenium interrelations in the diet of Atlantic salmon (*Salmo salar*): gross, histological and biochemical signs. *Journal of Nutrition* 106:892-904

Salmon data is in good agreement with trout data

Dietary selenium effect on rainbow trout fry growth:

- Dietary sodium selenite – 140 days
 - Optimum [Se]: about 1 $\mu\text{g/g}$
 - EC10 = 1.89 $\mu\text{g/g}$
- Dietary Selenomethionine – 90 days
 - Geomean = 1.70 $\mu\text{g/g}$



19.16
EPA
MATC
(maximum acceptable toxicant concentration)

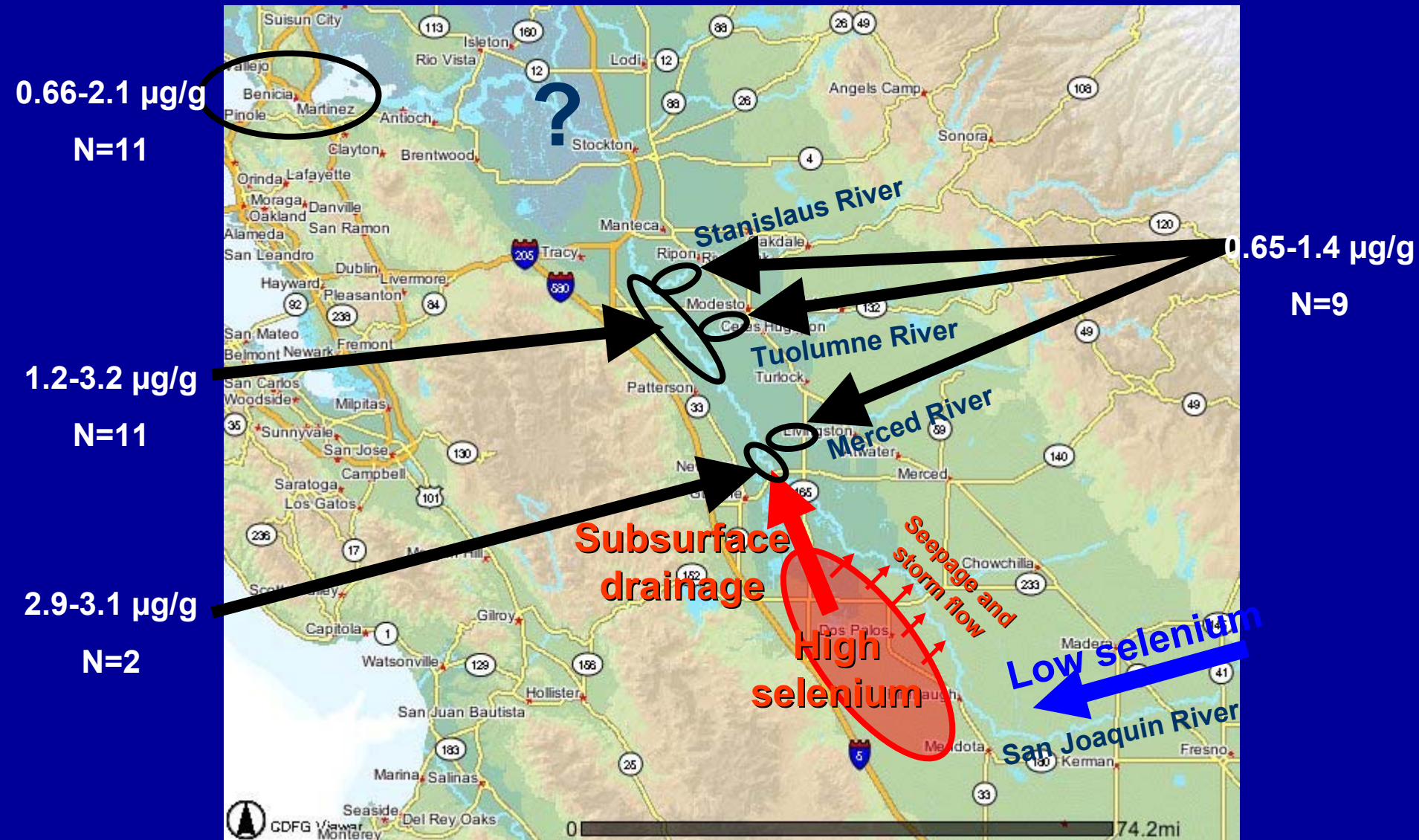
Hilton JW, Hodson PV, Slinger SJ. 1980. The requirement and toxicity of selenium in rainbow trout (*Salmo gairdneri*). *J Nutr* 110:2527-2535.

Vidal D, Bay SM, Schlenk D. 2005. Effects of dietary selenomethionine on larval rainbow trout (*Oncorhynchus mykiss*). *Arch Environ Contam Toxicol* 49:71-75.

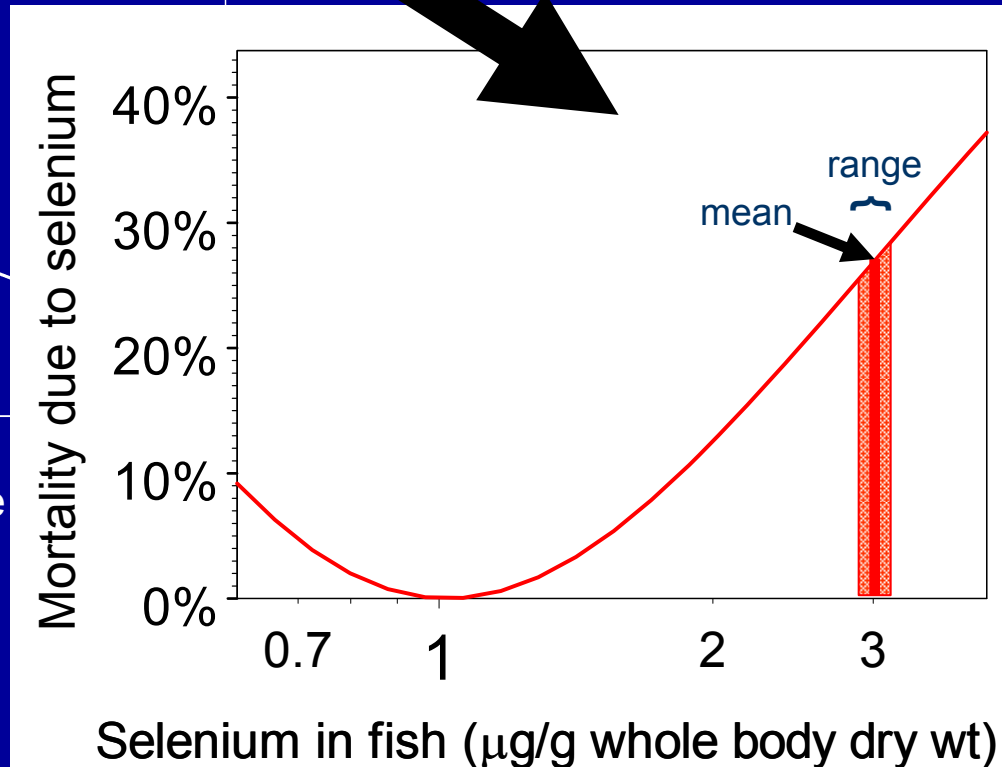
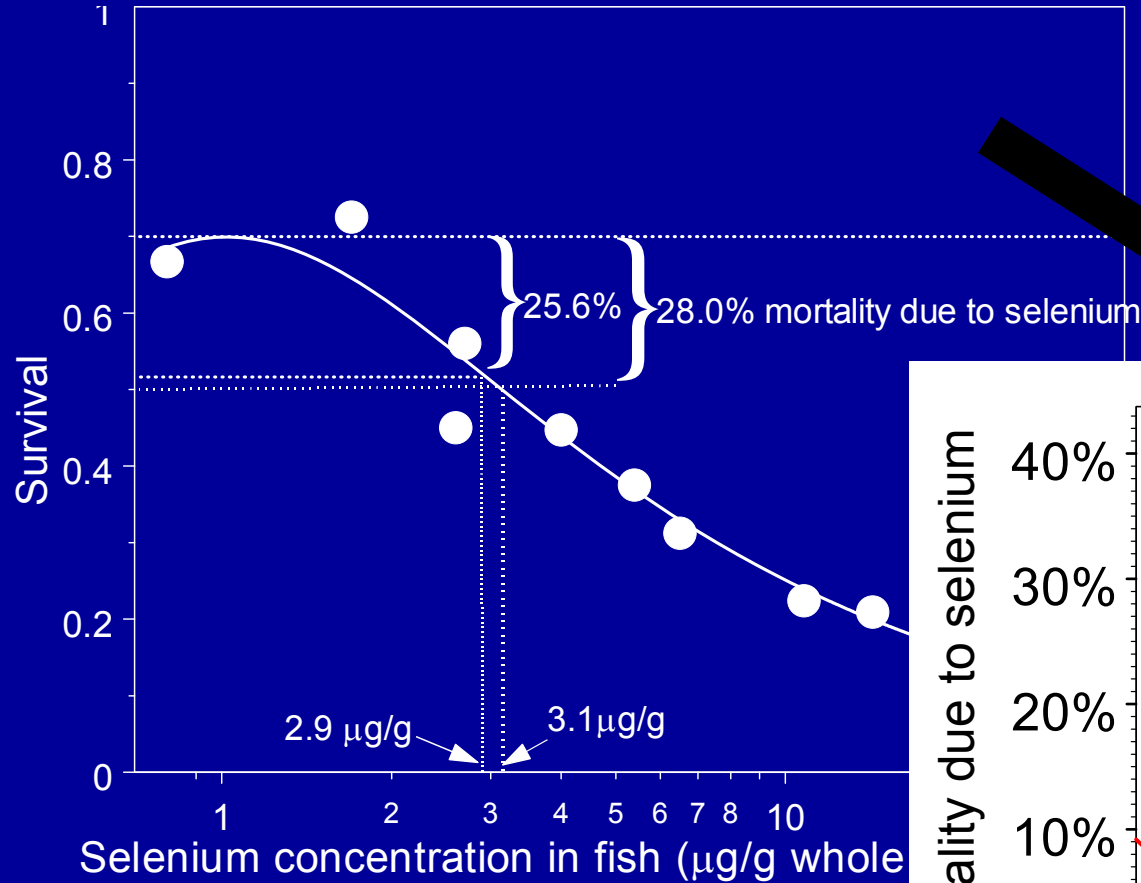
Do young migrating salmon actually linger long enough in the contaminated portions of rivers to bioaccumulate selenium to levels of concern?

Selenium in juvenile salmon 1986-1987

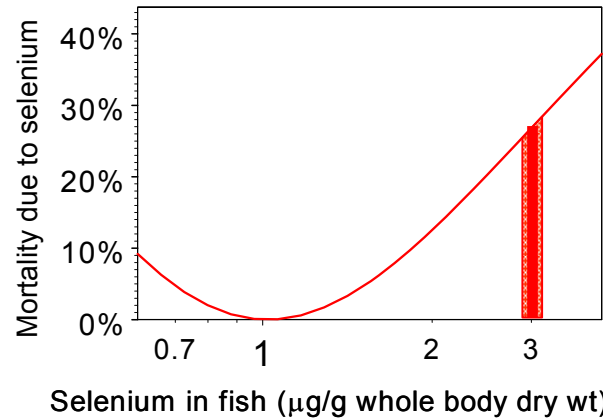
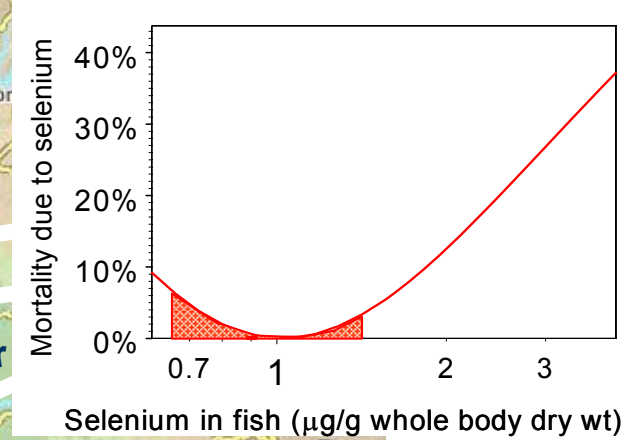
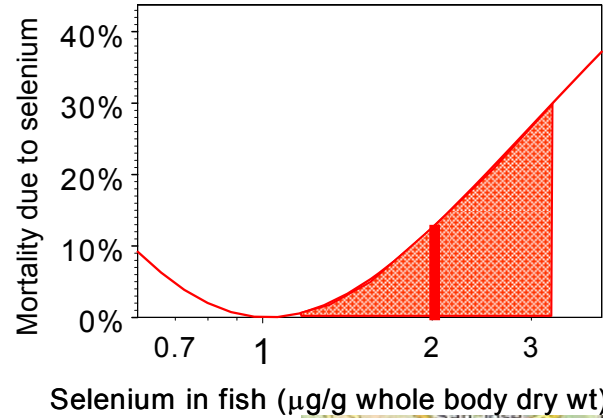
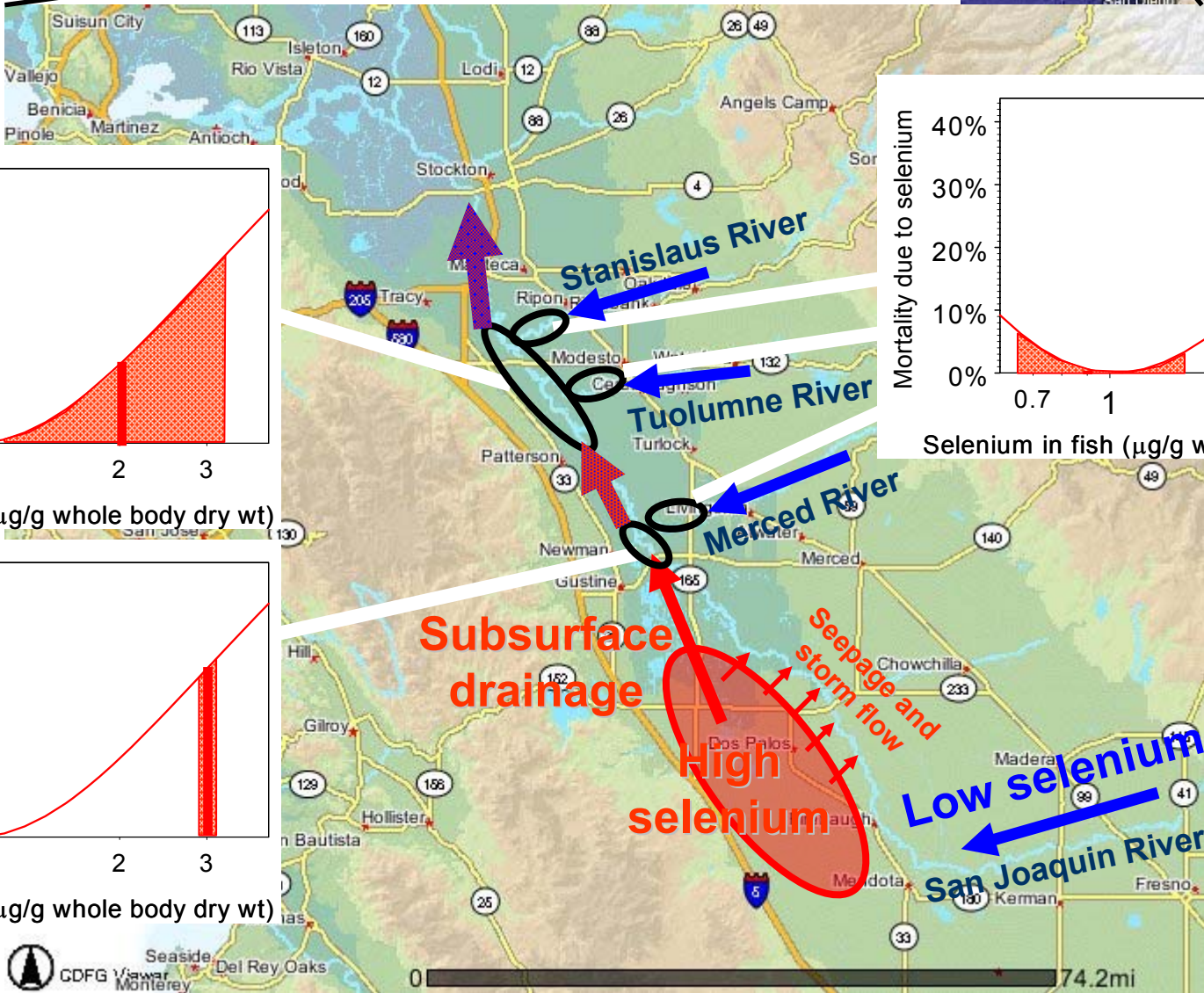
Saiki, Jennings, and Hamilton 1991



What do these selenium levels in fish mean?



Selenium risk to juvenile salmon



0 74.2mi

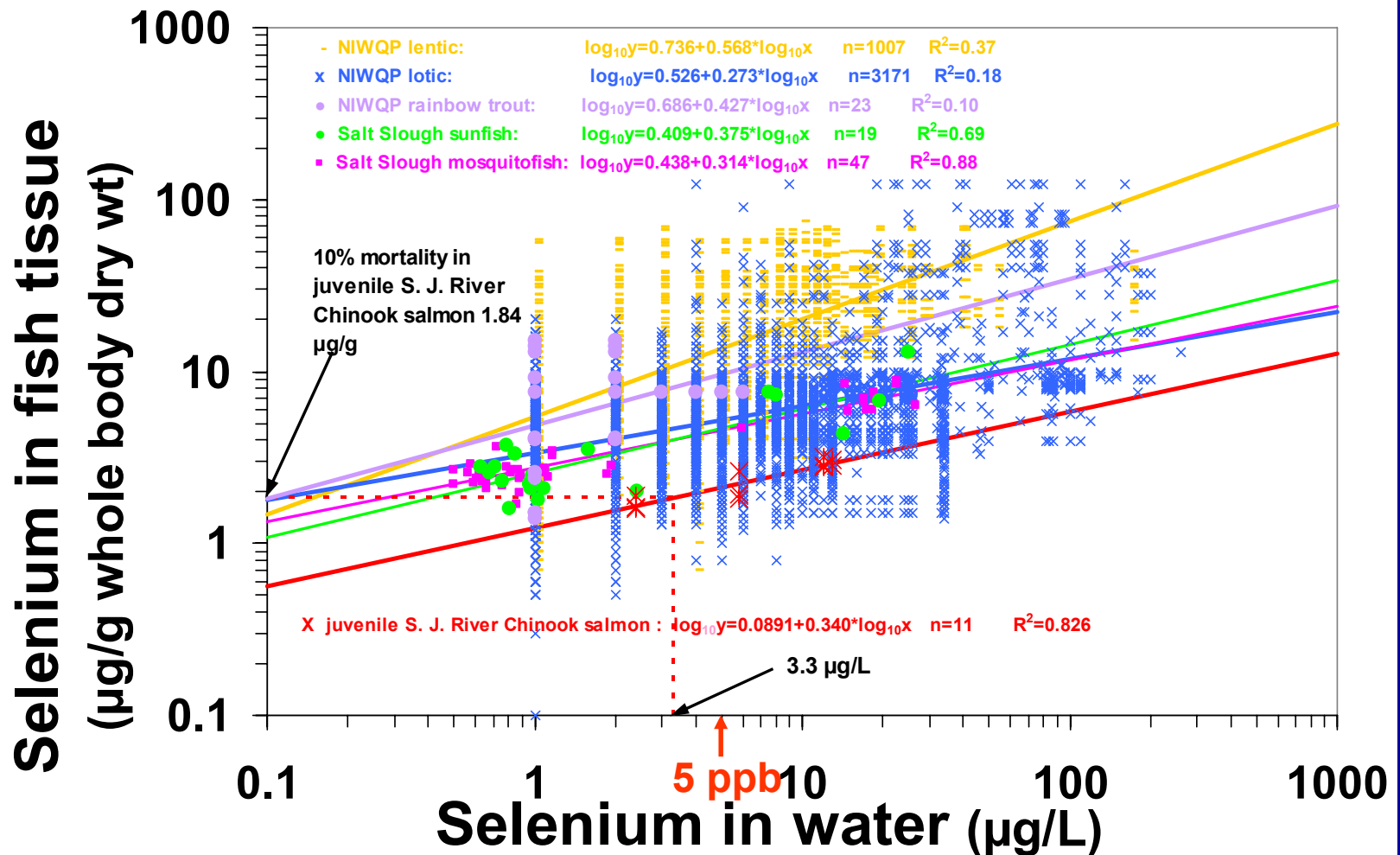
That was 1986-1987.

What about now?

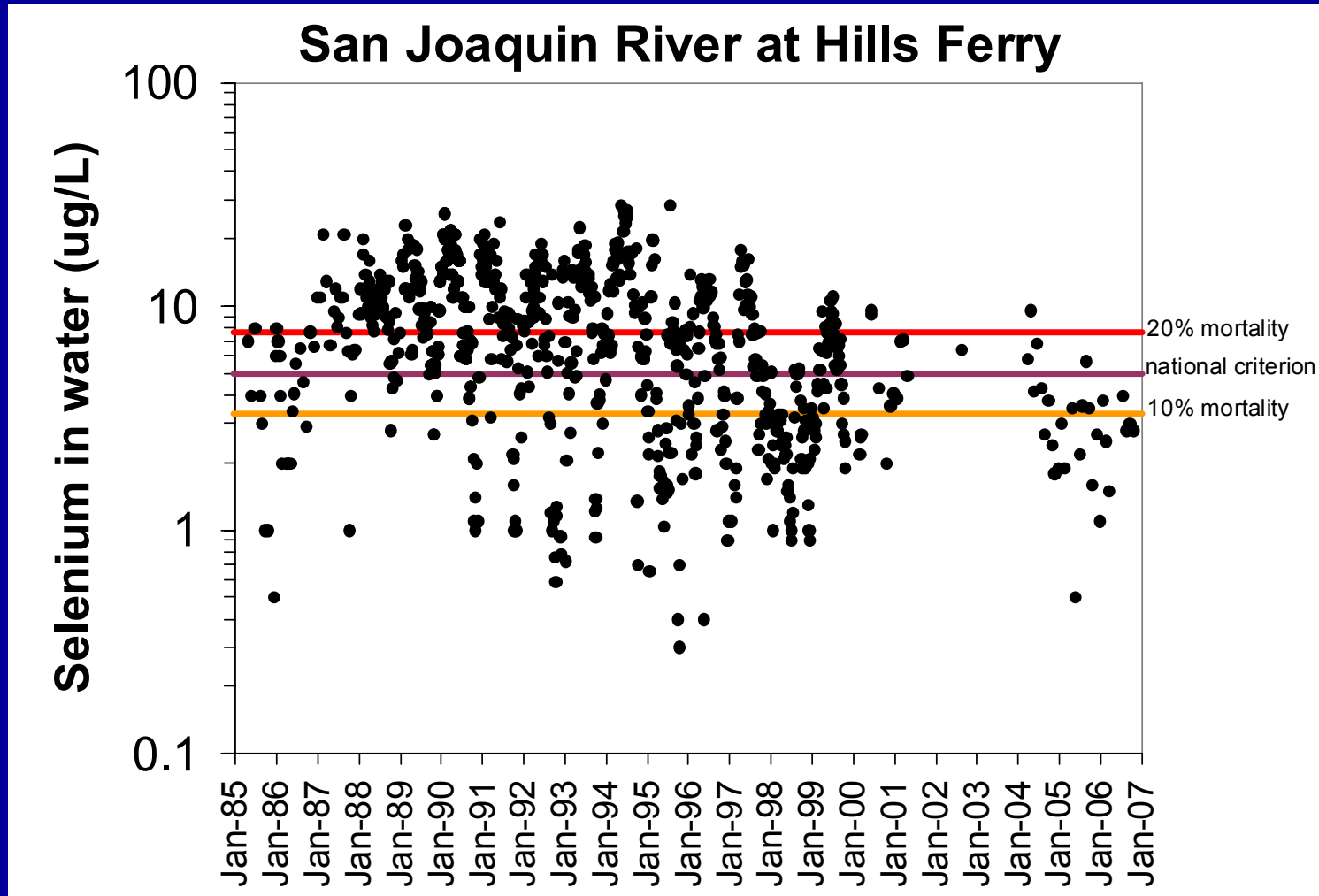
- Agricultural drainage management has reduced selenium discharge to the SJ River.

Bioaccumulation:

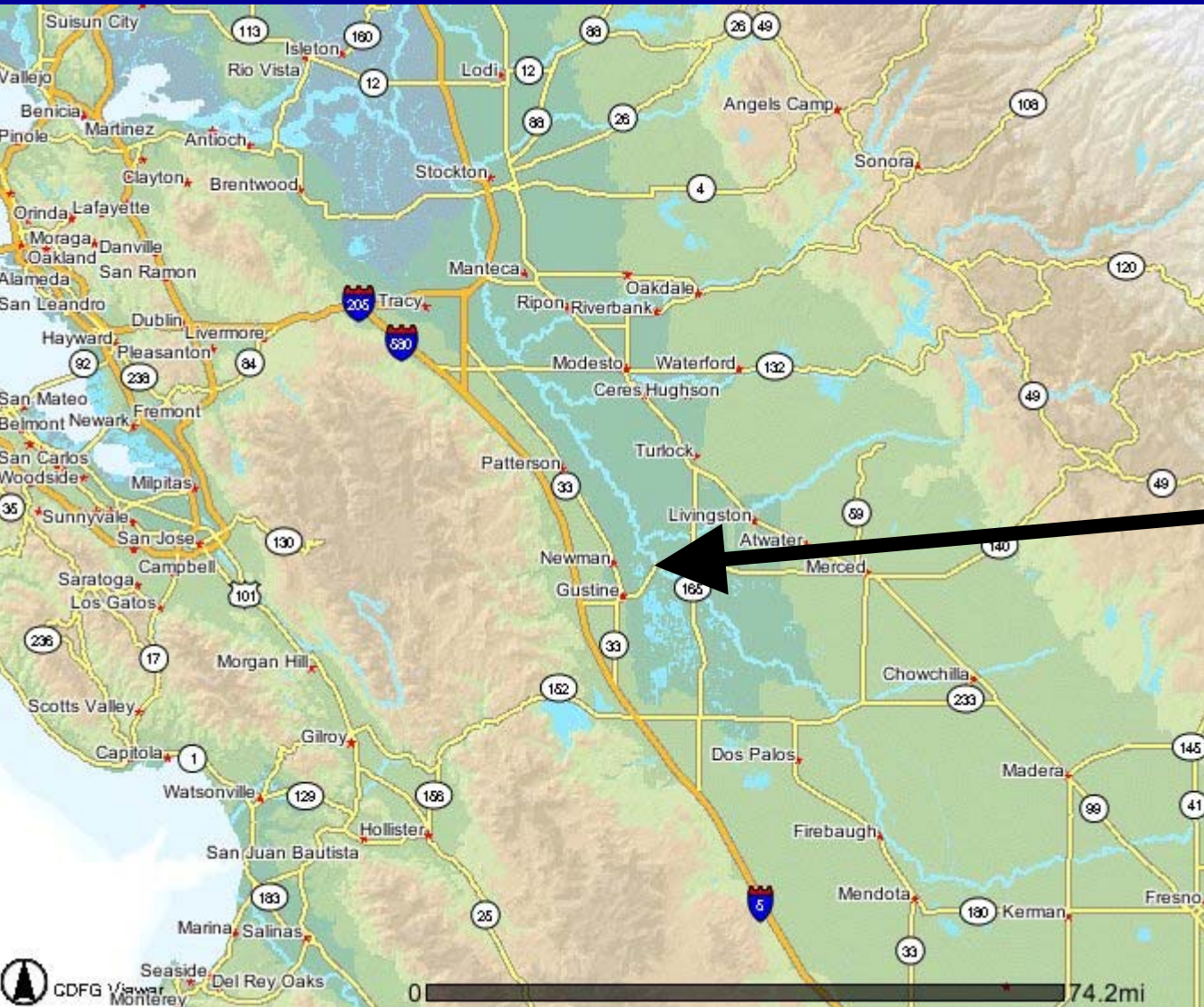
Relationship between selenium in fish tissue and selenium in water



Selenium in the San Joaquin River remains above salmon effect levels



Conclusion



- Selenium may have killed about a quarter of young salmon passing through this part of the San Joaquin River in the 1980s.
- Could kill >10% now.

...unless selenium in the River
is reduced
or flows increased.

Thank you

- Mike Saiki
- Kevin Buhl
- Tom Maurer
- Ralph Seiler