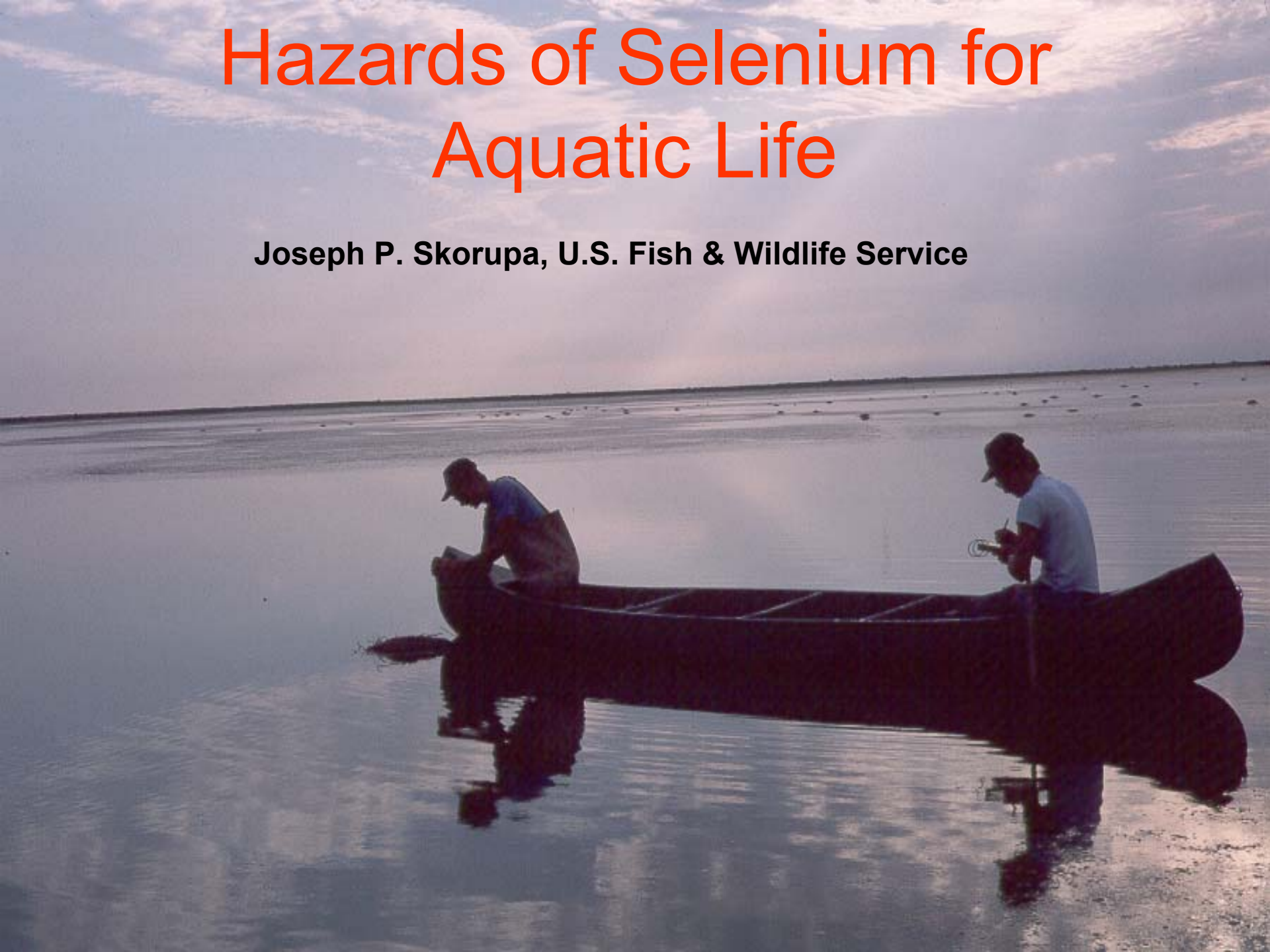
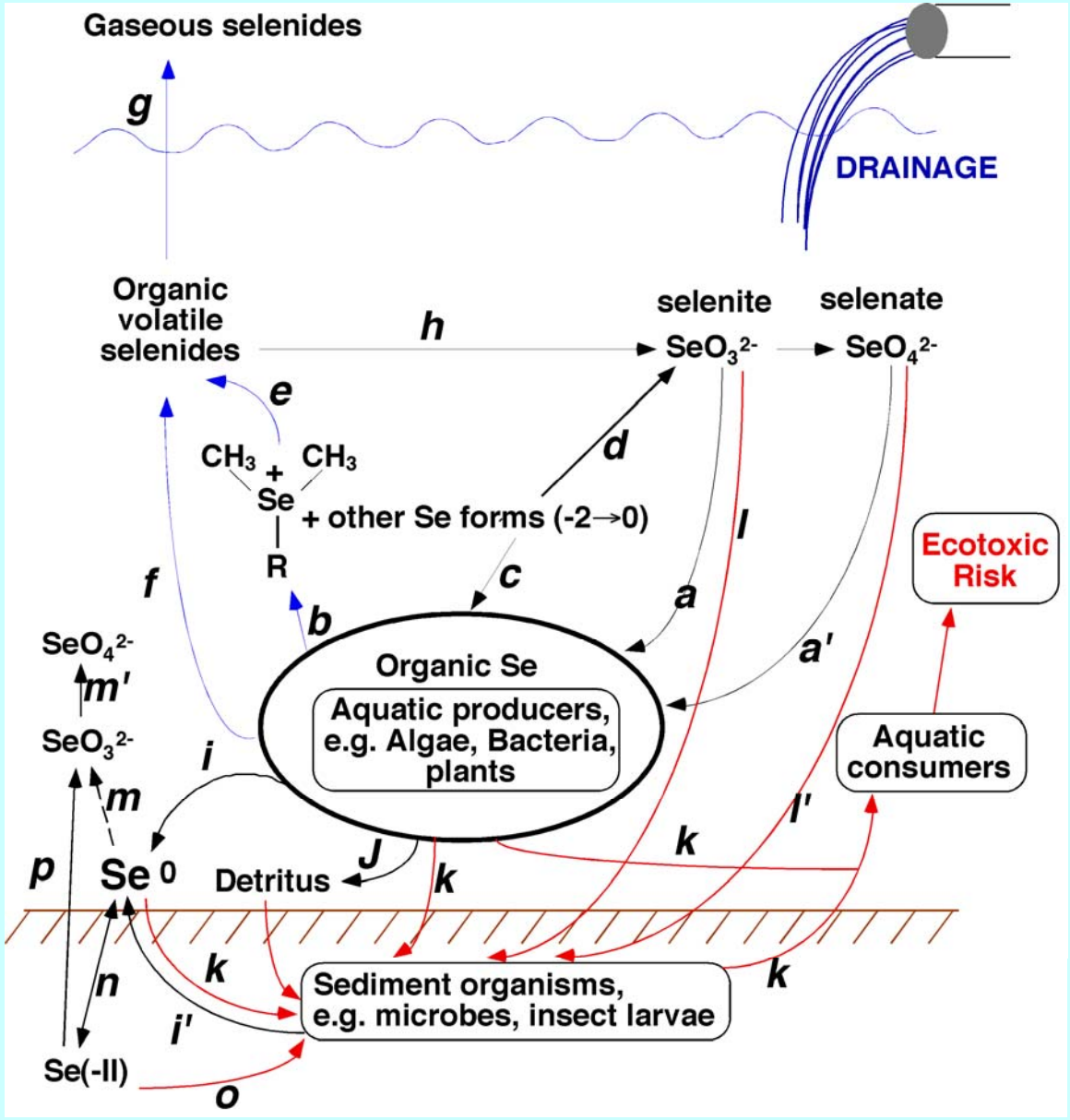
Hazards of Selenium for Aquatic Life

Joseph P. Skorupa, U.S. Fish & Wildlife Service

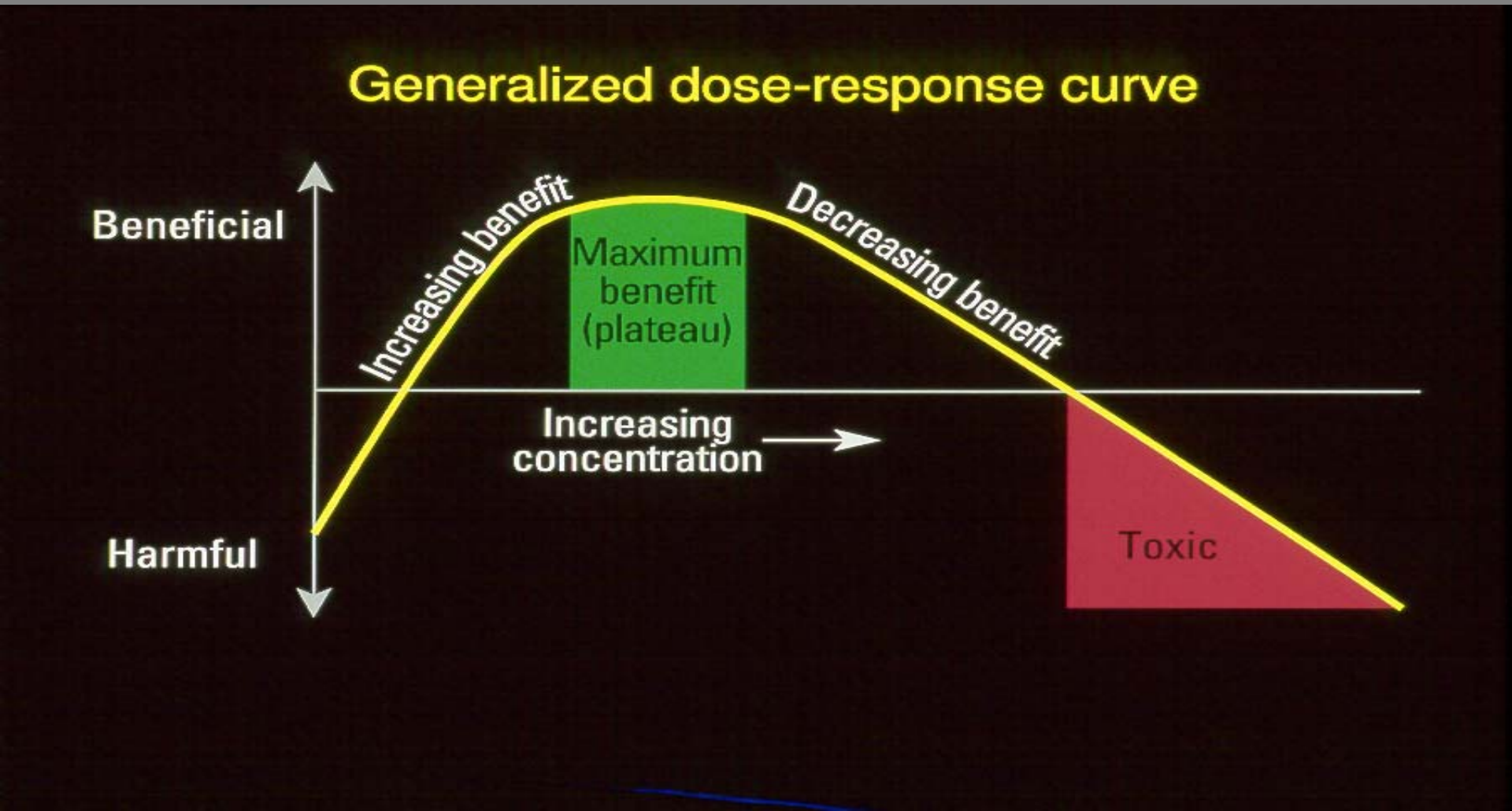


- Aquatic Life will be considered broadly to include both fish & aquatic-dependent wildlife.

SELENIUM ENVIRONMENTAL CHEMISTRY IS COMPLEX

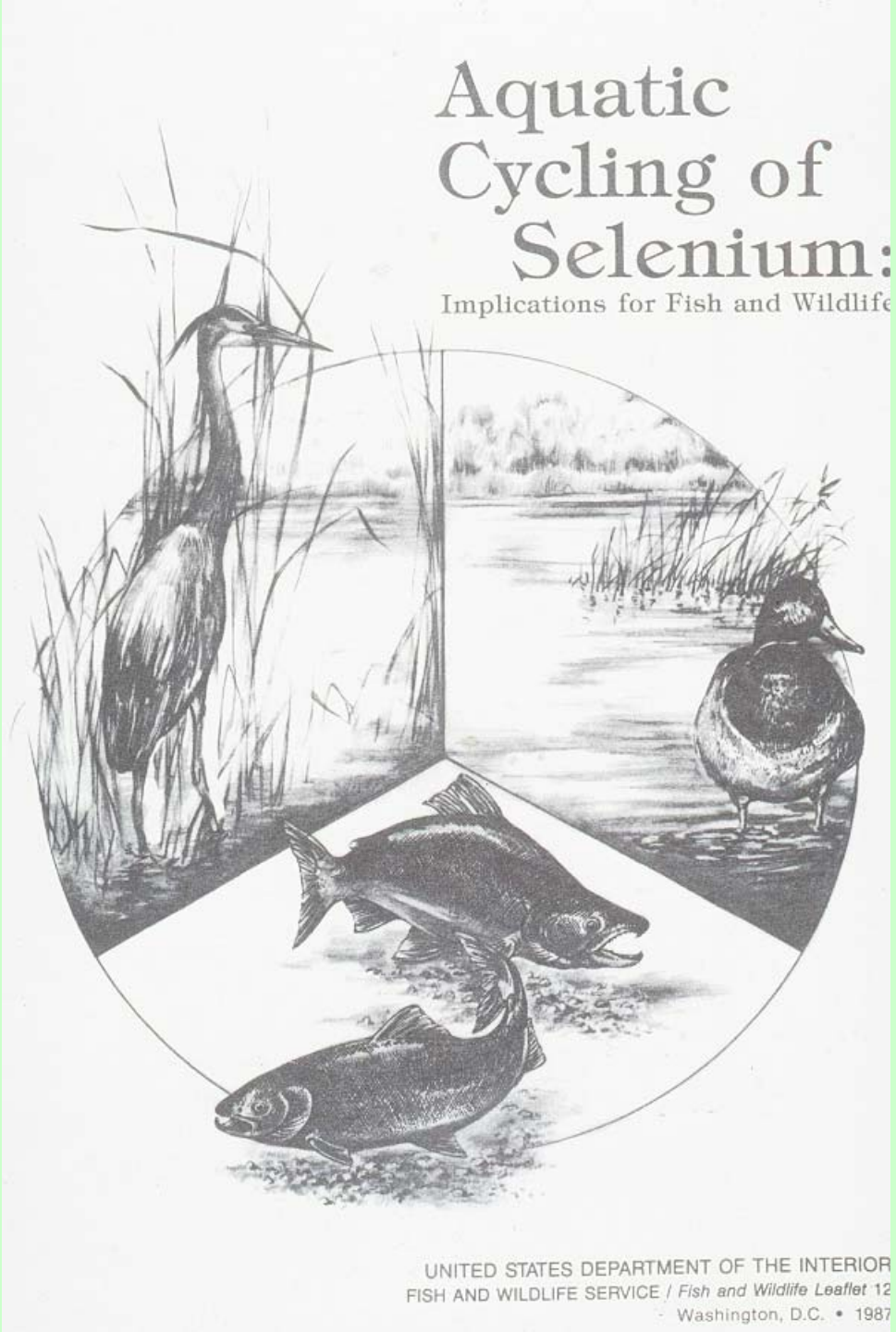


- **SELENIUM IS HORMETIC**
- **THE BENEFICIAL RANGE IS VERY NARROW**



THE NARROW TOLERANCE RANGE WAS FIRST ESTABLISHED FOR FREE-RANGE LIVESTOCK

- Following toxic episodes at Belews Lake, NC, and Kesterson Reservoir, CA, the sensitivity of aquatic ecosystems began to receive much more attention from ecotoxicologists.

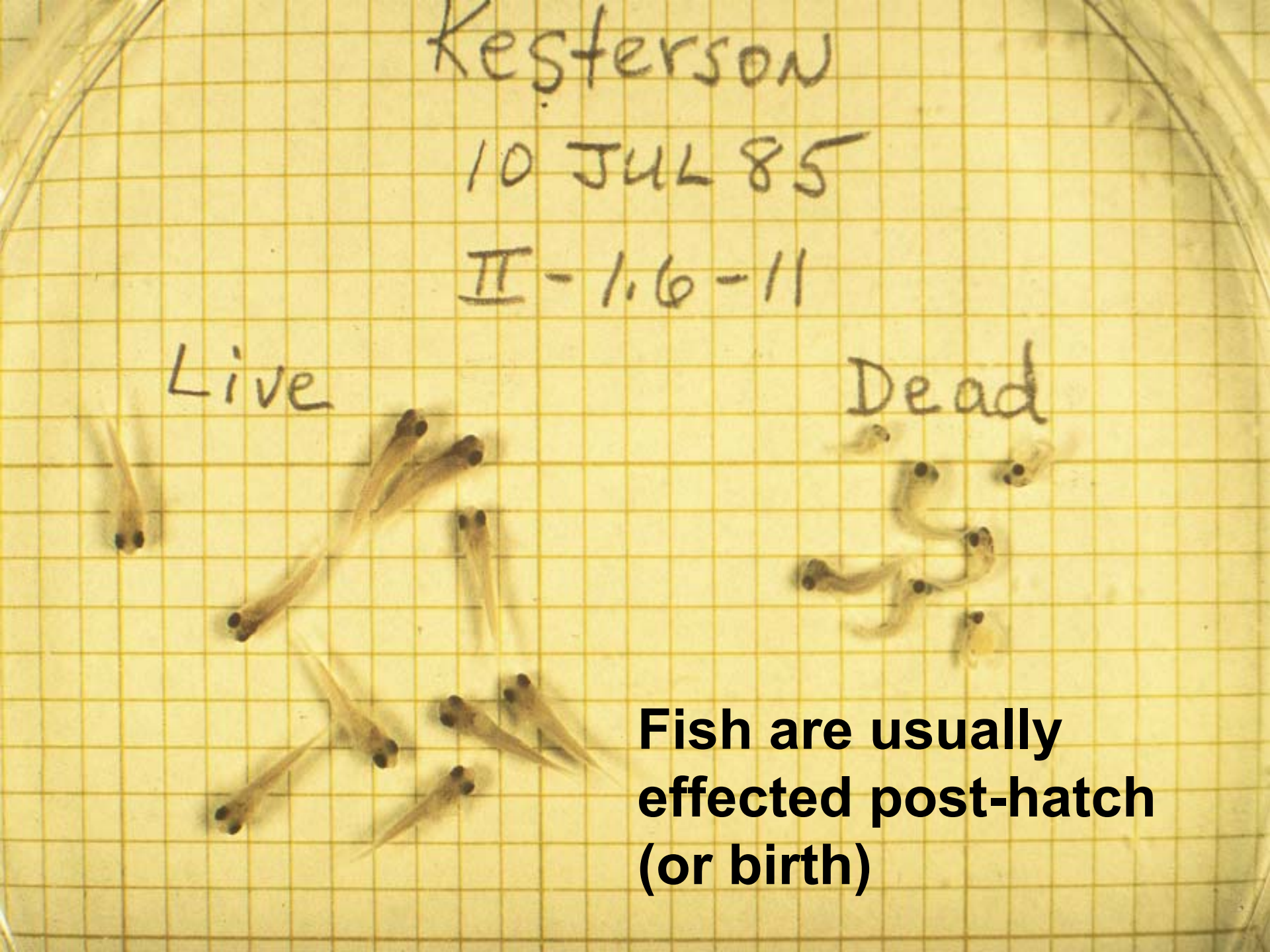


DIETARY EXPOSURE OF VERTEBRATE CONSUMERS IS THE HIGH-RISK PATHWAY FOR SELENIUM TOXICITY

Black-necked stilt foraging on brine flies averaging 55 ug/g Se


Deposition of selenium into eggs, via the maternal diet can cause reproductive impairment; often the most sensitive endpoint.


Poor egg hatchability is a common effect for waterbirds



Fish are usually effected post-hatch (or birth)

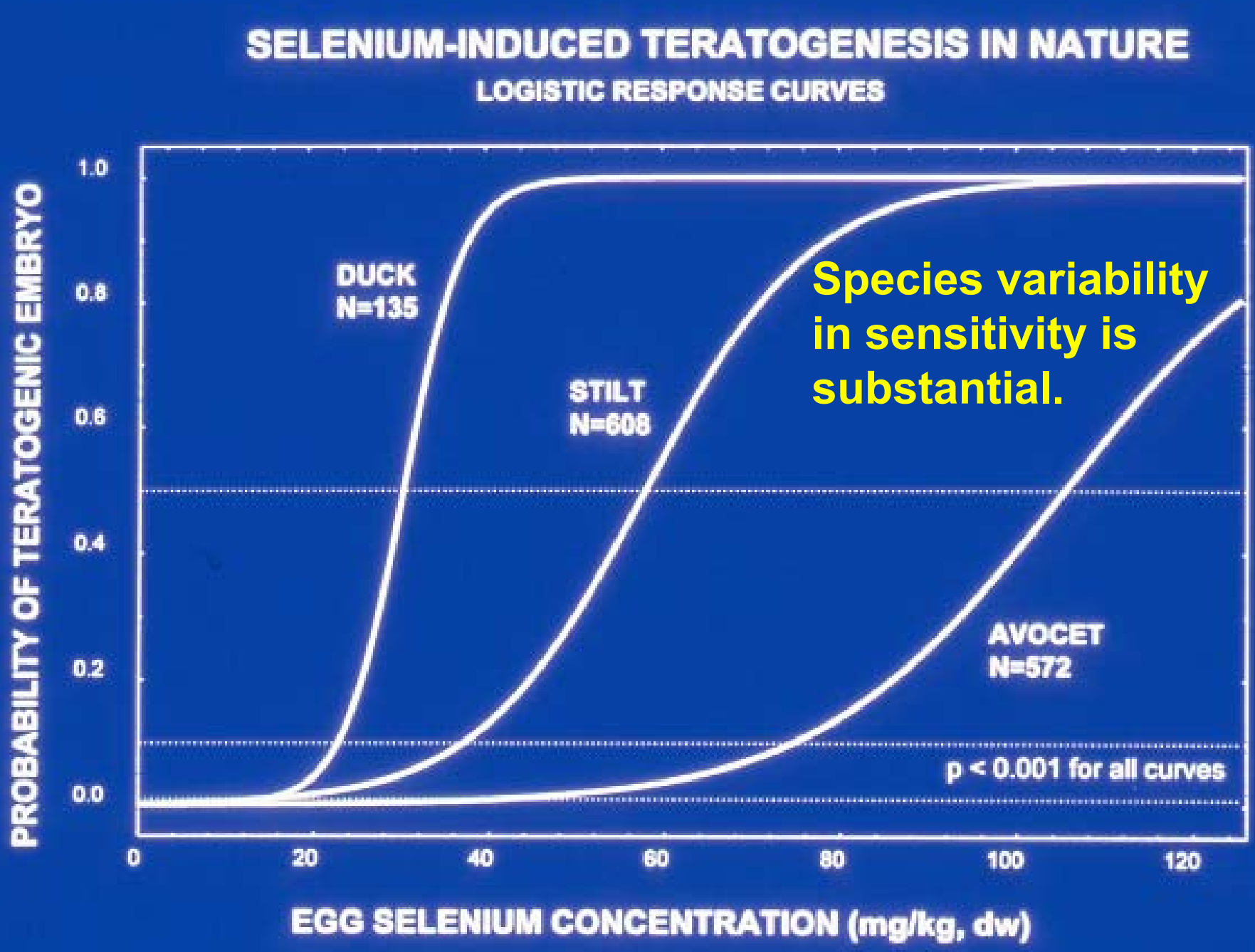
Avian eggs that fail to hatch may also contain overtly deformed embryos.

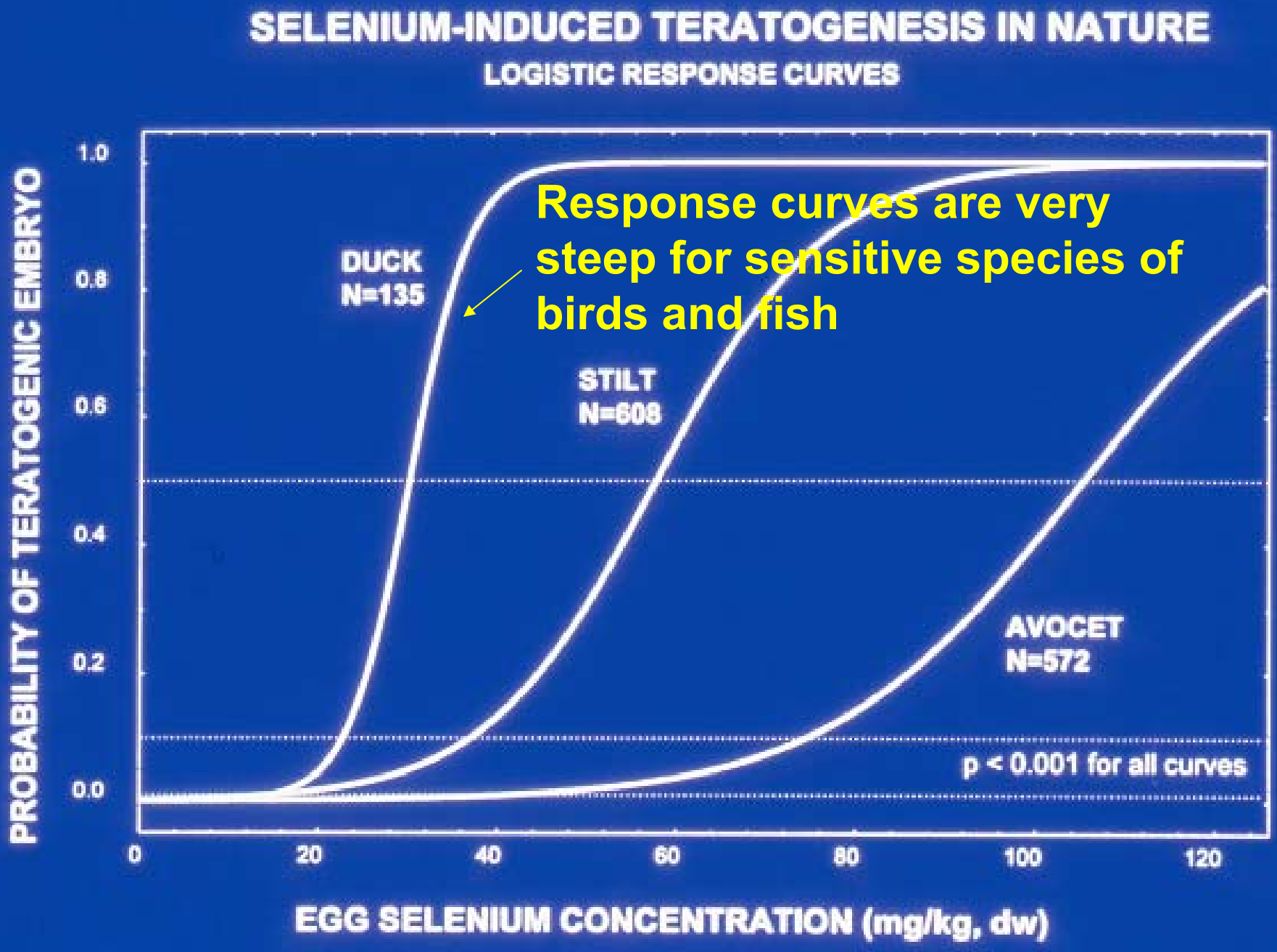
But nonteratogenic hatching failure occurs at lower exposure levels.

M-42

A B C

Teratogenic effects are often very consistent within a taxon across different geographic locations


SELENIUM-INDUCED TERATOGENESIS IN NATURE
LOGISTIC RESPONSE CURVES
PROBABILITY OF TERATOGENIC EMBRYO
1.0
0.8
0.6
0.4
0.2
0.0
DUCK
N=135
STILT
N=608
AVOCET
N=572
Species variability in sensitivity is substantial.
p < 0.001 for all curves
0
20
40
60
80
100
120
EGG SELENIUM CONCENTRATION (mg/kg, dw)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1.0
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Response curves are very steep for sensitive species of birds and fish
p < 0.001 for all curves
0
20
40
60
80
100
120
EGG SELENIUM CONCENTRATION (mg/kg, dw)

- Documented toxicity thresholds for sensitive taxa of fish and birds are convergent.

Selenium (ug/g dry wgt.)

Risk Thresholds for Sensitive Taxa of Aquatic Life

	None	Marginal	Substantive
Diet, ppm	<3	3 – 7	>7
Fish, ppm, (whole-body)	<4	4 – 6	>6
Avian eggs, ppm	<6	6 – 10	>10

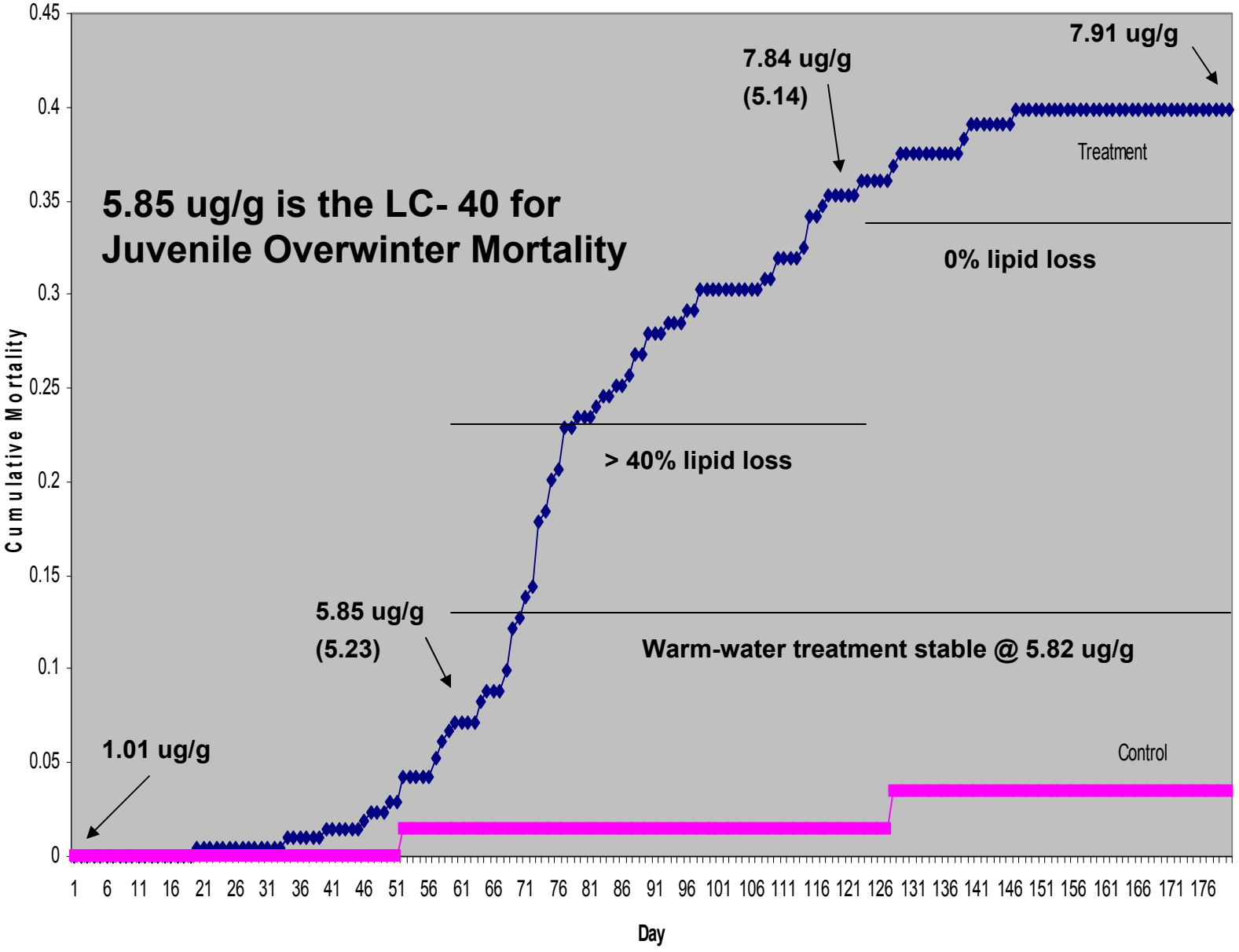
Sources:

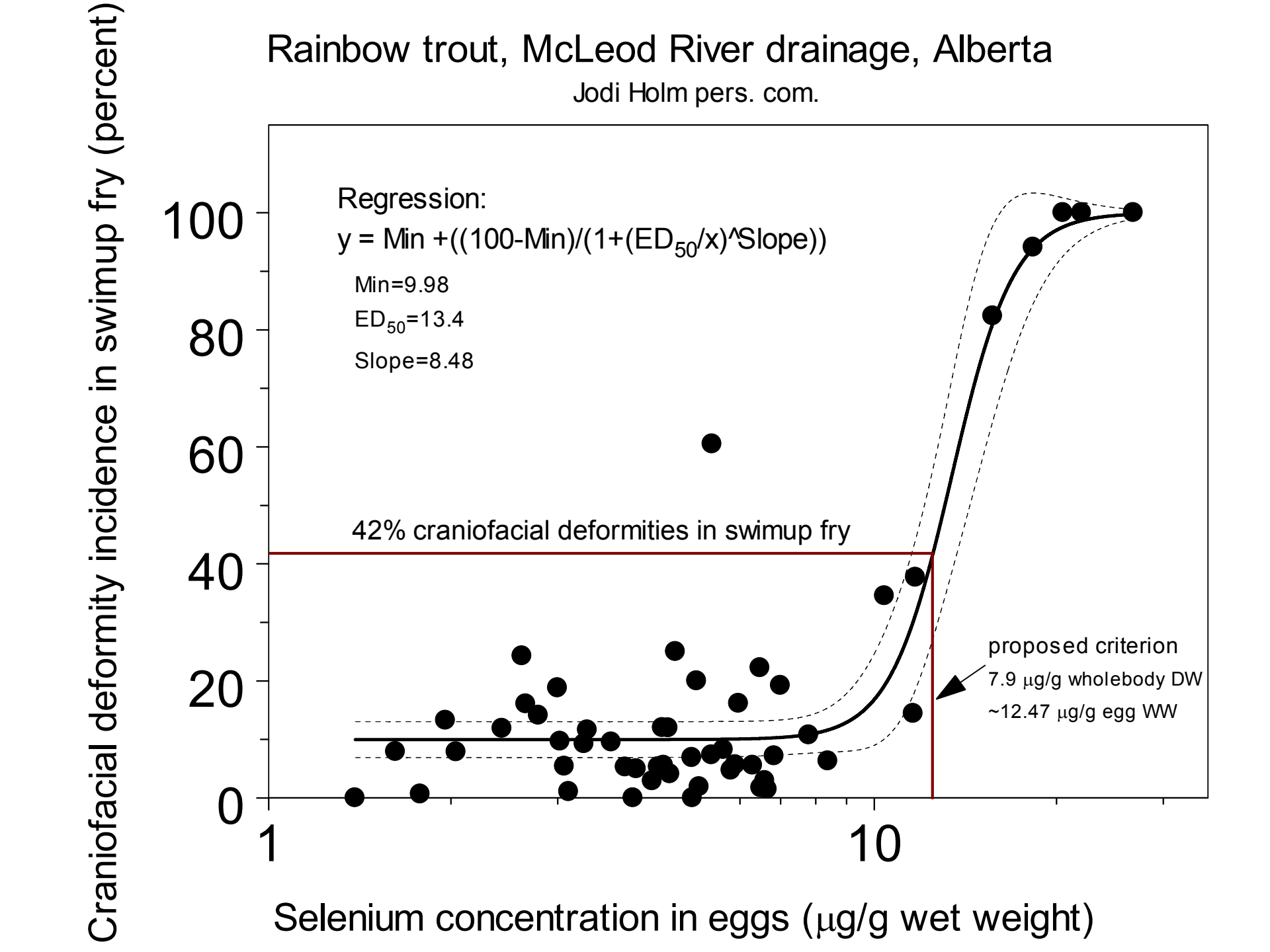
CAST (1994); Heinz (1996); Lemly (1996); DOI (1998); Ohlendorf (2003); Presser et al. (2004)

LEMLY RAW DATA

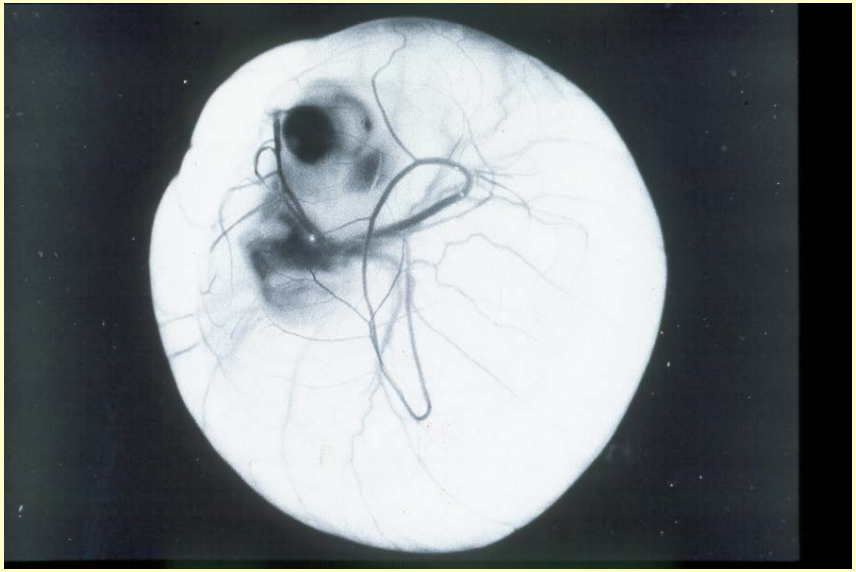
Cold + Se Treatment Day	Fish at Start	Fish at End	Fish Exposure Days	Dead Fish	Dsurv	Cmort
50	205	204	204.5	1	0.995122	0.028572
51	204	204	204	0	1	0.028572
52	204	201	202.5	3	0.985294	0.042858
53	201	201	201	0	1	0.042858
54	201	201	201	0	1	0.042858
55	201	201	201	0	1	0.042858
56	201	201	201	0	1	0.042858
57	201	199	200	2	0.99005	0.052381
58	199	197	198	2	0.98995	0.061905
59	197	196	196.5	1	0.994924	0.066667
60	196	195	195.5	1	0.994898	0.071429
Whole-body Se = 5.85 ug/g			**30 fish removed**			
61	165	165	165	0	1	0.071429
62	165	165	165	0	1	0.071429
63	165	165	165	0	1	0.071429
64	165	163	164	2	0.987879	0.082684
65	163	162	162.5	1	0.993865	0.088312
66	162	162	162	0	1	0.088312
67	162	162	162	0	1	0.088312
68	162	160	161	2	0.987654	0.099567
69	160	156	158	4	0.975	0.122078
70	156	155	155.5	1	0.99359	0.127706
			3825	**20**		
			5.23 mortalities per	**1,000 Exp.**	**Days**	

Lemly winter-stress results




Rainbow trout, McLeod River drainage, Alberta
Jodi Holm pers. com.
Regression:
y = Min +((100-Min)/(1+(ED50/x)^Slope))
Min=9.98
ED50=13.4
Slope=8.48
42% craniofacial deformities in swimup fry
proposed criterion
7.9 µg/g wholebody DW
~12.47 µg/g egg WW
Craniofacial deformity incidence in swimup fry (percent)
Selenium concentration in eggs (µg/g wet weight)
0
20
40
60
80
100
1
10

Concluding Comments



- Risk thresholds are for sensitive endpoints, of sensitive species, and EC-05 or lower effect level.
- Egg hatchability is the most sensitive endpoint for birds.
- Post-hatch viability of fry/larvae and overwinter juvenile survival are sensitive endpoints for fish.
- Mallards are a sensitive bird spp.
- Bluegill are a sensitive warmwater fish spp.
- Rainbow trout are a sensitive coldwater fish spp.
- Additional exposure-response curves for the above endpoints and sensitive taxa will further inform us regarding toxicity thresholds.
- Endpoints such as species presence/absence, relative abundance, and age structure are informative only with regard to catastrophic toxicity, not threshold toxicity; especially in demographically open populations.