APPENDIX I

SUMMARIES OF CHRONIC STUDIES CONSIDERED FOR FCV DERIVATION

Dobbs, M.G., D.S. Cherry, and J. Cairns, Jr. 1996. Toxicity and bioaccumulation of selenium to a three-trophic level food chain. Environ. Toxicol. Chem. 15:340-347.

Test Organism: Rotifer (*Brachionus calyciflorus*), and fathead minnow (*Pimephales promelas*) 12 to 24 hr-old at start.

Exposure Route: Dietary and waterborne

Water
Filtered and sterilized natural creek water supplemented with nutrients (Modified Guillard's Woods Hole Marine Biological Laboratory algal culture medium) for algal growth. Sodium selenate (Na_2SeO_4) was added to test water to obtain nominal concentrations of 100, 200, or 400 µg Se/L. Concentrations remained stable and equal in each trophic level.

Control Diet
No selenium was added to the water medium for the alga; green alga was free of selenium for the rotifer; and rotifers were free of selenium for the fathead minnow.

Selenium Diet
Sodium selenate was added to the culture medium for the alga; green alga thereby contained a body burden for the rotifer; and rotifers thereby contained a body burden for the fathead minnow.

Dietary Treatments: Each trophic level had a different treatment. The green alga was exposed directly from the water (1, 108.1, 204.9, 397.6 µg total Se/L); rotifers were exposed from the water (1, 108.1, 204.9, 393.0 µg total Se/L) and the green alga as food (2.5, 33, 40, 50 µg Se/g dry wt.); and the fathead minnow were exposed from water (1, 108.1, 204.9, 393.0 µg total Se/L) and the rotifer as food (2.5, 47, 53, 60 µg Se/g dry wt.).

Test Duration: 25 days

Study Design: A flow-through system utilizing a stock solution of filtered and sterilized creek water controlled at 25°C was used to expose three trophic levels of organisms. Approximately one liter of media was pumped from the algal chamber into the rotifer chamber each day. A cell density between 3 and 6×10^6 cells/ml was delivered to the rotifer chambers. Rotifers were started at a density of 151.4 ± 7.7 females/ml and one liter/day of rotifers containing culture water was intermittently pumped into the minnow chamber. (*B. calyciflorus* have a life span of about 7 days at 25°C.) The pump was necessary to overcome the swimming ability of rotifers to avoid an overflow tube. Larval fathead minnows (35/chamber) were prevented from escaping by a screened overflow. Chambers were cleaned daily and aeration was provided. All chambers were duplicated for test replication and water was measured for selenium on days 0, 2, 6, 7, 11, 14, 17, 20, and 24. All algal and rotifer biomass and selenium samples were made on these days. Fathead minnow chambers were measured for biomass, dissolved selenium, and tissue selenium concentrations of days 0, 7, 11, 14, 20, and 24. Additional measurements were made in the 200 µg Se/L test chambers on the fathead minnow on day 16. Selenium concentrations were maintained near the nominal concentrations and the standard deviation of mean concentrations was less than 4 percent.

Effects Data: Rotifers. Rotifers did not grow well and demonstrated reduced survival at all selenium exposure concentrations during the 25 day test. By test day 7 only the lowest test concentration (108.1 µg/L) had surviving rotifers which showed a decrease in selenium content from test days 18 through 25. A reduction in rotifer biomass was discernable by test day 4 in the selenium treatments and since all test concentrations had viable rotifer populations present, the effect level was calculated using these data.

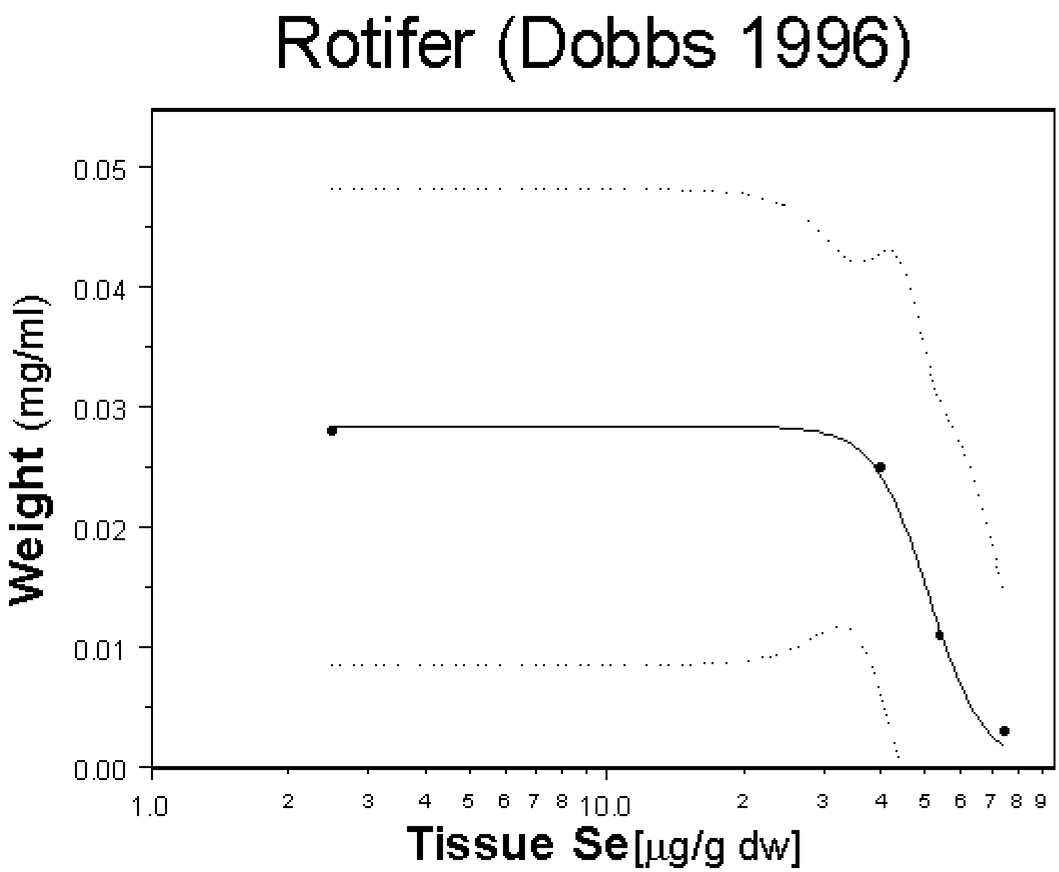
Effect of Dietary and Waterborne Selenium on Rotifers after 4 Days Exposure			
Se in water, µg/L	Se in diet, µg/g dw	Se in rotifer tissue, µg/g dw	rotifer biomass, mg/ml dw
1	2.5	2.5	0.028
108.1	33	40	0.025
202.4	40	54	0.011
393	50	75	0.003

Fathead minnows. Due to the reduction of rotifer biomass in the higher test concentrations, fish mortality and reduction in fish growth observed in the latter days of the test was difficult to discern between effects from starvation and selenium toxicity. The data from test day 8 was selected for determining the effect of selenium on fathead minnows because starvation could be excluded as a variable.

Effect of Dietary and Waterborne Selenium on Larval Fathead Minnows after 8 Days Exposure			
Se in water, µg/L	Se in diet, µg/g dw	Se in fathead minnow tissue, µg/g dw	average fish weight, mg dw
1	2.5	2.5	0.8
108.1	47	45	0.7
202.4	53	75	0.4
393	60	73	0.2

Chronic Value:

Rotifers	42.36 µg Se/g dw (EC_{20})
Fish	< 73 µg Se/g dw (LOAEC)-not amenable to statistical treatment; the LOAEC was based on the observation that a >50 percent reduction in mean fish weight occurred at this tissue concentration.



Hamilton, S.J., K.J. Buhl, N.L. Faerber, R.H. Wiedermeyer and F.A. Bullard. 1990. Toxicity of organic selenium in the diet of chinook salmon. Environ. Toxicol. Chem. 9:347-358.

Test Organism: Chinook salmon (*Oncorhynchus tshawytscha* Walbaum; swim-up larvae)

Exposure Route: Dietary only

Control Diet

Oregon moist pellet diet where over half of the salmon meal was replaced with meal from low-selenium mosquitofish (1.0 µg Se/g dw) collected from a reference site.

Selenium Diet #1

Oregon moist pellet diet where over half of the salmon meal was replaced with meal from high-selenium mosquitofish (35.4 µg Se/g dw) collected from the San Luis Drain, CA, termed SLD diet.

Selenium Diet #2

Oregon moist pellet diet where over half of the salmon meal was replaced with meal from low-selenium mosquitofish same as in the control diet, but fortified with seleno-DL-methionine (35.5 µg Se/g dw), termed SeMet diet.

Dietary Treatments: Each selenium diet was formulated to contain about 36 µg Se/g dw as the high exposure treatment. The remaining treatments were achieved by thoroughly mixing appropriate amounts of high-exposure treatment diet with control diet to yield the following nominal concentrations (3, 5, 10, and 18 µg Se/g dw).

Test Duration: 90 days

Study Design: Each dietary treatment was fed twice each day to swim-up larvae (n=100) in each of two replicate aquaria that received 1 L of replacement water (a reconstituted experimental water that simulated in quality a 1:37 dilution of water from the San Luis Drain, CA minus the trace elements) every 15 minutes (flow-through design). Mortality was recorded daily. Growth was evaluated at 30-day intervals by measuring the total lengths and wet weights of two subsets of individual fish (n=10x2) held in separate 11.5 L growth chambers within each replicate aquarium. Tissue samples were collected for whole-body selenium determinations (dry wt. basis) at 30-day intervals throughout the study; 10, 5, and 2 fish were sampled from each duplicate treatment after 30, 60, and 90 days of exposure, respectively. Concentrations of selenium measured in water were below the limit of detection (1.5-3.1 µg/L) in all dietary selenium exposure concentrations.

Effects Data: The magnitude of reduced growth was most evident in the weight of the fish, although total length was significantly reduced in fish fed high Se-laden diets as well. The effect of increasing dietary selenium on mean larval weight was similar in both the SLD and seleno-methionine diets.

Effect of San Luis Drain Diet on Growth and Survival of Chinook Salmon Larvae after 60 Days			
Se in diet, µg/g dw	Se in chinook salmon, µg/g dw	mean larval weight, g	survival, %
1	0.9	3.35	99
3.2	3.3	2.68	97.3
5.3	4.5	2.76	93
9.6	8.4	2.8	95
18.2	13.3	2.62	92.4
35.4	29.4	1.4	89

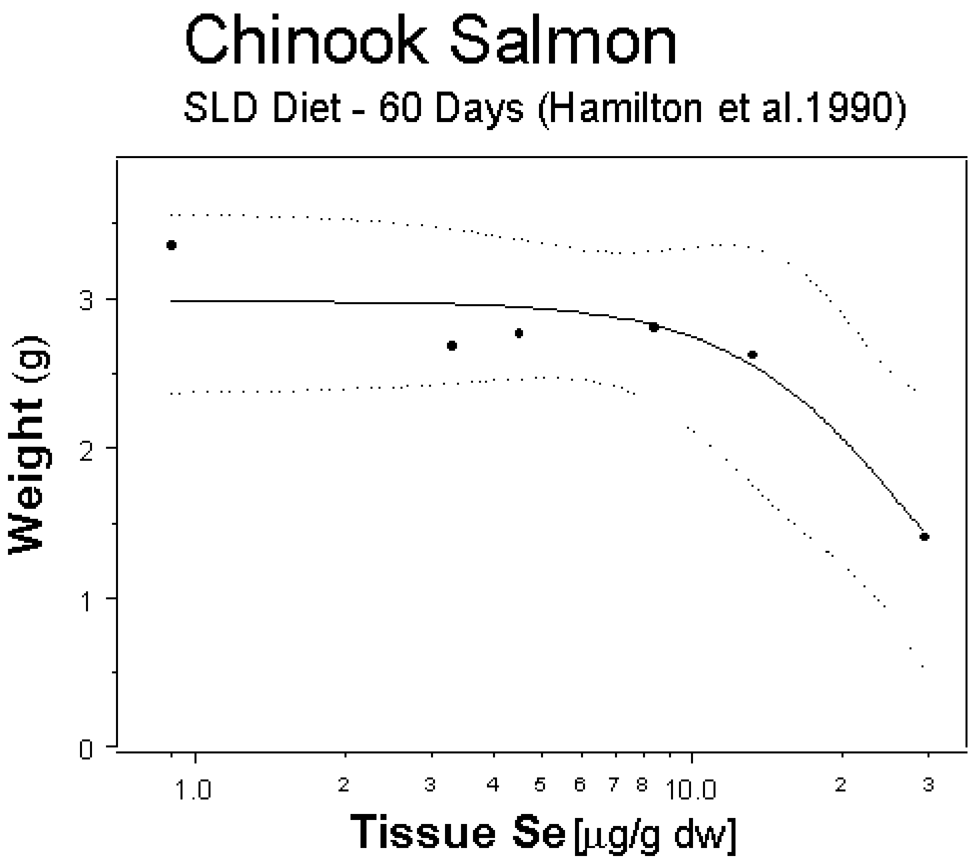
Effect of Seleno-methionine Diet on Growth and Survival of Chinook Salmon Larvae after 60 Days			
Se in diet, µg/g dw	Se in chinook salmon, µg/g dw	mean larval weight, g	survival, %
1	0.9	3.35	99
3.2	2	3.08	100
5.3	3.1	3.22	95
9.6	5.3	3.07	94.1
18.2	10.4	2.61	92.4
35.4	23.4	1.25	62.5

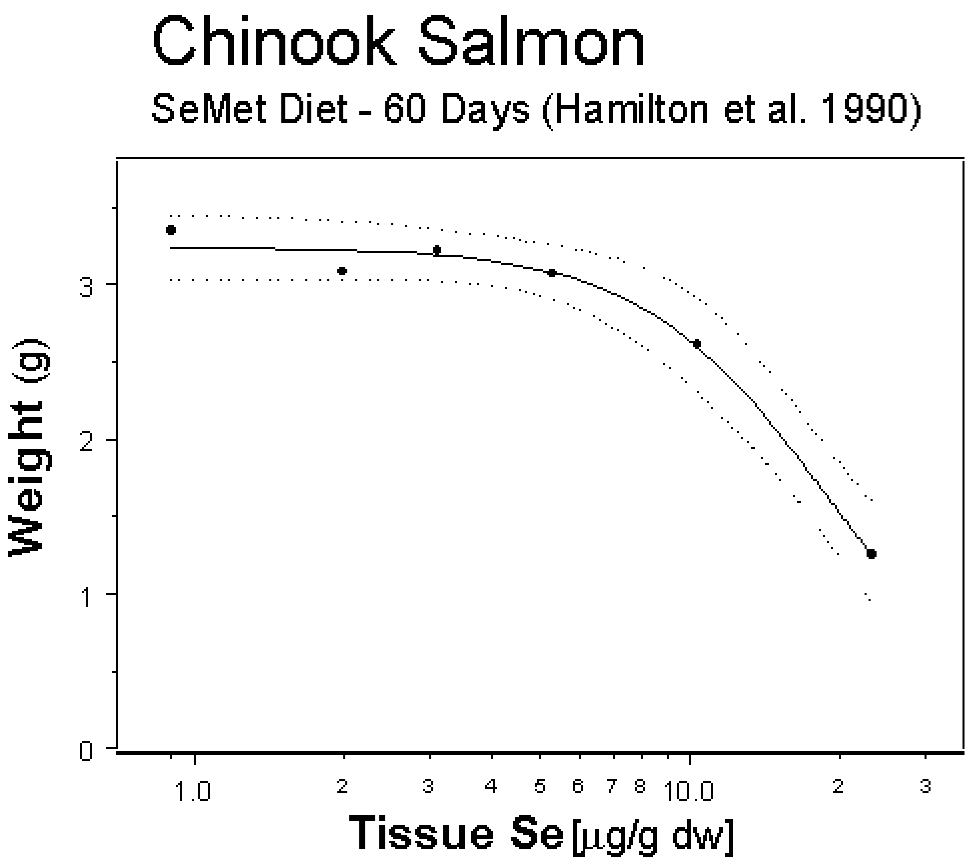
Chronic Value: Due to unacceptable control mortality of swim-up larvae in control treatments after 90 days (33.3 percent - SLD diet; 27.5 percent - SeMet diet), chronic values had to be determined from respective values reported after 60 days (tables above).

Analysis of the elemental composition of the SLD diet indicated that B, Cr, Fe, Mg, Ni and Sr were slightly elevated compared to the control and SeMet diets. No additional analyses were performed to determine the presence of other possible contaminants, i.e., pesticides.

	EC_{20} values	
	Survival (after 60 d of exposure)	Growth (after 60 d of exposure)
Diet type	Tissue Se (µg/g dw)	Tissue Se (µg/g dw)
SLD	NA[a]	15.74
SeMet	NA[a]	10.47

[a] The EC_{20} values for survival of swim-up larvae versus levels of selenium for the SLD and SeMet dietary exposure could not be estimated using non-linear regression.


Chinook Salmon
SLD Diet - 60 Days (Hamilton et al.1990)
Weight (g)
0
1
2
3
1.0
2
3
4
5
6
7
8
10.0
2
3
Tissue Se [μg/g dw]


Chinook Salmon
SeMet Diet - 60 Days (Hamilton et al. 1990)
Weight (g)
0
1
2
3
1.0
2
3
4
5
6
7
8
10.0
2
3
Tissue Se [µg/g dw]

Hilton, J.W. and P.V. Hodson. 1983. Effect of increased dietary carbohydrate on selenium metabolism and toxicity in rainbow trout (*Salmo gairdneri*). J. Nutr. 113:1241-1248.

Test Organism: Rainbow trout (*Oncorhynchus mykiss*; juvenile; approx. 0.6 g each)

Exposure Route: Dietary only

Low carbohydrate diet (LCD)

This diet contained capelin oil at 11 percent of the diet with cellulose as the filler.

High carbohydrate diet (HCD)

This diet contained cerelose at 25 percent of the diet with cellulose as the filler.

For both diets, the selenium was supplemented as sodium selenite which was mixed with cellulose and then added to the diet as a selenium premix.

Test Treatments: The two diets were supplemented with selenium (as sodium selenite) at the rate of 0, 5, or 10 µg/g dw to make up the six different dietary selenium treatments (n = 3 low carbohydrate diet; n= 3 high carbohydrate diet). The six diets were fed to duplicate groups of 100 fish. The trout were fed to satiation 3-6 times per day. Measured concentrations of selenium in the low carbohydrate diet were: 0.6 (control), 6.6, and 11.4 µg/g dw, and the measured concentrations of selenium in the high carbohydrate diet were: 0.7 (control), 6.6, and 11.8 µg/g dw. The tanks received a continuous flow of water with a flow rate of 3-4 Liters per minute.

Test Duration: 16 weeks

Study Design: Body weights, feed:gain ratios, and total mortalities were determined after each 28-day interval. After 16 weeks, approximately 20 fish were randomly removed from each tank, weighed, and blood was collected for hemoglobin, hematocrit, and plasma glucose, protein, and calcium determination. The livers and kidneys were then dissected. The livers were assayed for glycogen content, and samples of both liver and kidney were assayed for selenium content. Additional subsamples of fish were sacrificed and assayed for selenium content and for ash, crude protein, and moisture content (n=6 per treatment). Finally, 30 fish were killed, their livers and kidneys dissected, and analyzed for Ca, Cu, Fe, Mg, P, and Zn content.

Effects Data: The only overt sign of selenium toxicity was food avoidance observed in trout fed the highest selenium content in both low and high carbohydrate diets, which led to significantly reduced body weight after 16 weeks. There were no significant differences detected between treatment groups in hematological parameters. Kidney, liver, and carcass selenium levels increased with increasing selenium content of the diet, however, only the liver selenium concentrations were significantly affected by dietary selenium level, dietary carbohydrate level, and the interaction between the two treatments. Mineral analysis of the kidney showed significantly higher levels of calcium and phosphorous in trout reared on the two highest levels of dietary selenium. Concentrations of copper in the liver increased significantly with increasing dietary selenium levels and decreasing dietary carbohydrate levels.

Effect of Selenium in Low carbohydrate Diet to Rainbow Trout		
Se in diet, µg/g dw	Se in trout liver, µg/g dw	trout weight, kg/100 fish
0.6	0.8	3.3
6.6	38.3	3.3
11.4	49.3	1.8

Effect of Selenium in High carbohydrate Diet to Rainbow Trout		
Se in diet, µg/g dw	Se in trout liver, µg/g dw	trout weight, kg/100 fish
0.7	0.6	2.7
6.6	21.0	2.3
11.8	71.7	1.4

Chronic Value: The MATC estimated for growth of rainbow trout relative to final concentration of selenium in liver tissue of trout reared on the low carbohydrate diet is the GM of 38.3 (NOAEC) and 49.3 (LOAEC) µg/g dw, or 43.45 µg/g dw. The MATC estimated for growth of rainbow trout relative to final concentration of selenium in liver tissue of trout reared on the high carbohydrate diet is the GM of 21.0 (NOAEC) and 71.7 (LOAEC) µg/g dw, or 38.80 µg/g dw. Using equation III in the text to convert this selenium concentration in liver tissue to a concentration of selenium in whole-body, the MATC for rainbow trout exposed to selenium in food with low carbohydrate content becomes 13.08 µg Se/g dw., whereas the MATC for rainbow trout exposed to selenium in food with high carbohydrate content becomes 11.65 µg Se/g dw. The latter value is selected as the chronic value for the study.

EC_{20} values could not be determined for this study. Data did not meet minimum requirements for analysis.

Hicks, B.D., J.W. Hilton, and H.W. Ferguson. 1984. Influence of dietary selenium on the occurrence of nephrocalcinosis in the rainbow trout, *Salmo gairdneri* Richardson. J. Fish Diseases. 7:379-389.

(Note: These data are the exact same as reported for the low carbohydrate diet in Hilton and Hodson 1983, with the addition of prevalence of nephrocalcinosis occurring in trout after 16 to 20 weeks of consuming the contaminated test diets).

Test Organism: Rainbow trout (*Oncorhynchus mykiss*; juvenile; approx. 0.6 g each)

Exposure Route: Dietary only
This diet contained capelin oil at 11 percent of the diet with cellulose as the filler. The selenium was supplemented as sodium selenite which was mixed with cellulose and then added to the diet as a selenium premix.

Test Treatments: The test diet was supplemented with selenium (as sodium selenite) at the rate of 0, 5, or 10 µg/g dw to make up the three different dietary selenium treatments. The three diets were fed to duplicate groups of 100 fish. The trout were fed to satiation 3-6 times per day. Measured concentrations of selenium in the low carbohydrate diet were: 0.6 (control), 6.6, and 11.4 µg/g dw. The tanks received a continuous flow of water with a flow rate of 3-4 Liters per minute.

Test Duration: 16 to 20 weeks

Study Design: See Hilton and Hodson (1983). After 20 weeks on the test diets, ten fish were randomly removed from each treatment. Tissues for histopathological examination included the stomach, intestine and pyloric ceca (including pancreas), spleen, liver, heart, kidney, skin, muscle, and gills.

Effects Data: Only effects of selenium on kidney tissue are included in the article. The kidneys of the 10 trout fed the highest selenium content in the diet exhibited normal appearance. Five of these trout exhibited precipitation of calcium in the tubules with some epithelial necrosis, but no loss of epithelial continuity. Extensive mineralized deposition of Ca within the tubules, tubular dilation and necrosis of tubular epithelium, ulceration of tubules, and intestinal Ca mineralization was observed in four of the ten fish.

Chronic Value: Same as for growth of rainbow trout reported by Hilton and Hodson (1983). The MATC estimated for growth of rainbow trout relative to final concentration of selenium in liver tissue of trout reared on the low carbohydrate diet is the GM of 38.3 (NOAEC) and 49.3 (LOAEC) µg/g dw, or 43.45 µg/g dw. Using equation III to convert the selenium concentration in liver tissue to a concentration of selenium in whole-body, the MATC becomes 13.08 µg/g dw.

EC_{20} values could not be determined for this study. Data did not meet minimum requirements for analysis.

Hilton, J.W., P.V. Hodson, and S.J. Slinger. 1980. The requirements and toxicity of selenium in rainbow trout (*Salmo gairdneri*). J. Nutr. 110:2527-2535.

Test Organism: Rainbow trout (*Oncorhynchus mykiss*; juvenile; approx. 1.28 g each)

Exposure Route: Dietary only
A casien-torula yeast diet was formulated to contain geometrically increasing levels of selenium from 0 to 15 µg/g dw. The selenium was supplemented as sodium selenite which was mixed with cellulose and then added to the diet as a selenium premix.

Test Duration: 20 weeks

Study Design: Six test diets were fed to triplicate groups of 75 fish. The trout were fed to satiation 3-4 times per day, 6 days per week, with one feeding on the seventh day. Measured concentrations of selenium in the diet were: 0.07 (control), 0.15, 0.38, 1.25, 3.67, and 13.06 µg/g dw. The tanks received a continuous flow of dechlorinated tap water from the City of Burlinton, Ontario municipal water supply. The waterborne selenium content of this water was 0.4 µg/L. During the experiment, the fish were weighed every 2 weeks with the feeding level adjusted accordingly. Mortalities were noted daily and the feed consumption for each treatment was recorded weekly. After 4 and 16 weeks, three to six fish were randomly removed from each tank, sacrificed, and their livers and kidneys removed and weighed. An additional three to six fish were then obtained from each treatment, killed, and prepared for tissue analysis. Organs and carcasses were freeze-dried for determination of selenium concentration. After 16 weeks, three more fish were removed. Kidney, liver, spleen and dorsal muscle tissue was dissected for examination of histopathology. At the end of 8 and 16 weeks, four to five fish were removed, sacrificed, and a blood sample was taken for hematological measurements (hematocrit, red blood cell count, and blood iron concentration). After 20 weeks, three to four more fish were removed, sacrificed, and a blood sample was taken for measurement of glutathione peroxidase activity.

Effects Data: There were no significant differences detected between treatment groups in histopathology, hematology, or plasma glutathione peroxidase activity. Trout raised on the highest dietary level of selenium (13.06 µg/g dw) had a significantly lower body weight and a higher number of mortalities (10.7; expressed as number per 10,000 fish days) than trout from the other treatments levels after 20 weeks of exposure.

Effects on Juvenile Rainbow Trout			
Se in diet, µg/g dw	Se in Liver, µg/g dw	weight, g/fish	mortality*
0.07	0.6	3.2	0
0.15	0.95	3.5	0
0.38	2.4	3.7	0.6
1.25	11	4.1	0.6
3.67	40	4.1	0
13.06	100	1.4	10.7

*expressed as number per 10,000 fish-days

Chronic Value: An MATC was preferred over regression analysis because of the large standard error associated with the EC_{20} value. The MATC for the growth and survival of juvenile trout based on selenium in liver tissue is the GM of the NOAEC (40 µg/g dw) and the LOAEC (100 µg/g dw), or 63.25 µg Se/g dw. Using the equation III in the text to convert the selenium concentration in liver tissue to a concentration of selenium in whole-body tissue, the MATC becomes 19.16 µg/g dw.

Holm, J. 2002. Sublethal effects of selenium on rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*). Masters Thesis. Department of Zoology, University of Manitoba, Winnipeg, MB.

Holm, J., V.P. Palace, K. Wautier, R.E. Evans, C.L. Baron, C. Podemski, P. Siwik and G. Sterling. 2003. An assessment of the development and survival of rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*) exposed to elevated selenium in an area of active coal mining. Proceedings of the 26th Annual Larval Fish Conference 2003, Bergen, Norway. ISBN 82-7461-059-B.

Test Organism: Rainbow trout (*Oncorhynchus mykiss*; spawning adults) and brook trout (*Salvelinus fontinalis*; spawning adults)

Exposure Route: dietary and waterborne - field exposure
Total selenium concentrations measured at the high selenium site ranged from 6 to 32 µg/L. Selenium was not measured at the reference streams; selenium concentrations at reference locations in the area ranged from <0.5 to 2.2 µg/L.

Study Design: Spawning fish were collected at low selenium or reference streams (Deerlick Creek and Cold Creek), a slightly elevated selenium stream (Gregg Creek), and an elevated selenium stream (Luscar Creek) in the Northeastern slopes region of Alberta, Canada. An active coal mine is the source of selenium in the elevated streams. Eggs and milt from the spawning trout were expressed by light pressure from abdomen. Individual clutches of eggs were fertilized from a composite volume of milt derived from 3-5 males. Fertilized eggs from individual females were reared to swim-up stage and examined for a number of parameters including percent fertilization, mortality, edema, and deformities (craniofacial, finfold, and spinal malformations). Similar studies were conducted in both 2000 and 2001. One notable difference is that the embryos were incubated at 8°C in 2000 and at 5°C in 2001. The authors noted that 5°C is a better representation of the actual stream temperature during embryo development..

Effects Data : Other than selenium, there were no significant differences in the concentrations of other elements (Al, As, Sb, Ba, Be, Ni, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ag, Sr, Tl, Th, Sn, Ti, U, V, Zn) in trout eggs between the low level and elevated selenium streams. There are two ways to approach determination of effects due to selenium in this study and both are presented here. The first approach determines effects based on a comparison of average conditions between streams (*between streams approach*). For example, if there is a significant difference between the average frequency of deformities in a contaminated stream and reference stream, the effect level for the *between streams approach* would be the average concentration of selenium in the tissue from the contaminated stream. The second approach evaluates individual response variables (e.g., edema, deformities) against the individual selenium tissue concentrations for the combined contaminated and reference stream data set with each year (*within streams approach*). This approach, which results in an EC_{20} value if the data meet the model assumptions, is explained in the *Calculations of Chronic Values* section of the text.

Between streams approach: For both rainbow and brook trout embryos, there were no significant differences in fertilization, time to hatch and mortality between the streams with elevated selenium and the reference streams in both 2000 and 2001. The frequency of embryonic effects were significantly greater in the high selenium stream (Luscar Creek) in 2000. Rainbow trout embryos from Luscar Creek had a greater frequency of craniofacial, skeletal and finfold deformities and edema; whereas brook trout from Luscar Creek had a greater frequency of only craniofacial deformities (see Holm Tables 1 and 2 below). In 2001, however, there were no significant differences in embryonic deformities between Luscar Creek and reference streams for both species of trout. The only difference observed in 2001 was a greater frequency of finfold deformities in brook trout collected from Gregg Creek (intermediate selenium levels) relative to the reference stream (see Holm table 2 below). All other embryonic measurements in 2001 were not significantly different between streams with elevated selenium and reference streams. When the data for both years were pooled, no significant effects were observed in embryos obtained from rainbow and brook trout collected in Luscar Creek relative to reference streams (see Holm Table 3).

Within streams approach: EC_{20} values could not be calculated for total deformities or edema for the 2000 rainbow trout data because a logistic curve could not be fitted to the data (see Holm Figures 1 and 2). For the 2001 data, EC_{20} values could not be computed for edema and skeletal and finfold deformities for rainbow trout data because a logistic curve could not be fitted to the data (see Holm Figures 3 and 4). Craniofacial deformities in the rainbow embryo as a function of selenium in egg ww (2001 data) was fitted to a logistic curve from which an EC_{20} value was calculated (see Holm Figure 5). The brook trout data for 2000 and 2001 were not suitable for fitting logistic curves (see Holm Figure 6).

Holm Table 1
Mean embryo-larval parameters for rainbow trout collected from a high Se site (Luscar Creek), an intermediate Se site (Gregg River), and reference sites (Deerlick Creek and Wampus Creek) in northeastern Alberta over two consecutive years (mean ± SE). Values that are significantly different at $\alpha = 0.05$ are marked with different letters. (Table modified from Holm 2002)

Measurement	2000		2001			
	Luscar	Deerlick	Luscar	Gregg	Deerlick	Wampus
Se, egg, µg/g ww	8.37 ± 1.62	2.05 ± 1.06	6.49 ± 0.89	6.65 ± 1.83	2.77 ± 0.20	2.35 ± 0.31
Se, adult muscle, µg/g ww	1.50 ± 0.28	0.48 ± 0.15	NT	NT	NT	NT
n[a]	297	261	2021	720	1342	209
% fertilization	79.8 ± 4.3	51.5 ± 10.9	81.5 ± 5.0	79.4 ± 5.2	88.0 ± 2.1	94.0 ± 4.8
% mortality	3.3 ± 1.0	0.7 ± 0.4	27.8 ± 7.3	38.3 ±13.7	26.5 ± 4.7	4.2 ± 0.8
% CR	7.7 ± 3.7[b]	0.2 ± 0.2[c]	14.7 ± 3.4	11.7 ± 2.7	10.6 ± 1.9	12.0 ± 4.1
% SK	13.8 ± 5.6[b]	0.7 ± 0.5[c]	19.4 ± 8.2	11.1 ± 2.3	15.6 ± 4.7	4.9 ± 4.9
% FF	3.2 ± 2.0[b]	0.2 ± 0.2[c]	6.8 ± 3.0	15.5 ± 6.6	4.0 ± 0.9	1.5 ± 0.2
% ED	30.8 ± 27.4[b]	0.2 ± 0.2[c]	19.9 ± 8.5	13.9 ± 5.3	10.8 ± 2.5	7.5 ± 0.4
% TD	38.9 ± 25.6[b]	0.7 ± 0.5[c]	ND	ND	ND	ND

[a] number of fry to reach the swim-up stage
[b and c] statistically different values
CR = craniofacial defects, SK = skeletal defects, FF = finfold defects, ED = edema, TD = total defects, NT = not tested, ND = not done

Holm Table 2
Mean embryo-larval parameters for brook trout collected from a high Se site (Luscar Creek), an intermediate Se site (Gregg River), and reference sites (Cold Creek) in northeastern Alberta over two consecutive years (mean ± SE). Values that are significantly different at $\alpha = 0.05$ are marked with different letters. (Table modified from Holm 2002)

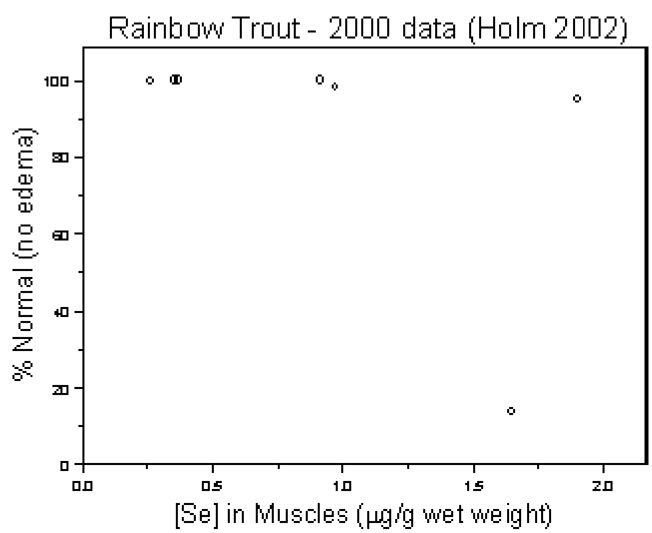
Site	2000		2001		
	Luscar	Cold	Luscar	Gregg	Cold
Se, egg, µg/g ww	6.37 ± 0.78	1.35 ± 0.24	8.02 ± 0.77	6.88 ± 0.51	1.25 ± 0.15
Se, adult muscle, µg/g ww	3.79 ± 0.51	0.55 ± 0.10	NT	NT	NT
n[a]	4904	1560	3440	1892	1440
% fertilization	97.4 ± 0.8	96.1 ± 1.2	87.2 ± 2.6	85.2 ± 5.4	77.8 ± 14.2
% mortality	12.6 ± 3.8	9.3 ± 2.4	2.9 ± 0.8	2.9 ± 0.9	3.7 ± 1.6
% CR	13.6 ± 3.5[b]	3.0 ± 0.5[c]	5.6 ± 3.2	2.12 ± 1.0	0.7 ± 0.3
% SK	1.9 ± 0.8	1.3 ± 0.8	2.1 ± 1.1	0.81 ± 0.3	0.6 ± 0.4
% FF	1.1 ± 0.6	1.2 ± 0.8	3.7 ± 1.8	4.1 ± 2.4[c]	0.1 ± 0.1[b]
% ED	0.6 ± 0.4	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.2	1.7 ± 1.2
% TD	14.4 ± 3.6[b]	4.0 ± 2.3[c]	ND	ND	ND

[a] number of fry to reach the swim-up stage
[b and c] statistically different values
CR = craniofacial defects, SK = skeletal defects, FF = finfold defects, ED = edema, TD = total defects, ND = not done

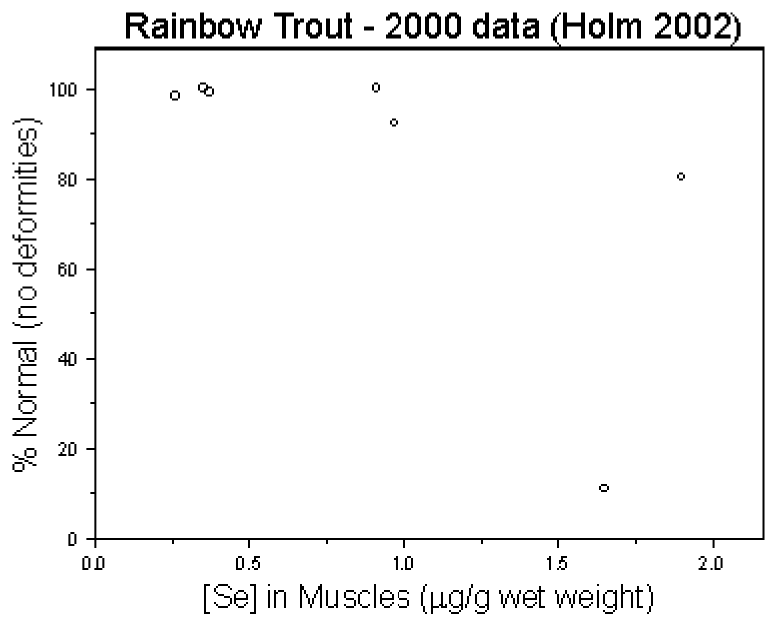
Holm Table 3
Mean embryo-larval parameters for rainbow trout and brook trout collected from a high Se site (Luscar Creek) and reference sites (Deerlick Creek and Cold Creek) in northeastern Alberta over two consecutive years, combined over both years of the study by site (mean ± SE). Values that are significantly different at $\alpha = 0.05$ are marked with different letters. (Table modified from Holm 2002)

Measurement	Rainbow Trout		Brook Trout	
	Luscar	Deerlick	Luscar	Cold
Se, egg, µg/g ww	6.92 ± 0.78	2.56 ± 0.32	7.20 ± 0.56	1.30 ± 0.14
n[a]	2318	1603	8344	3000
% fertilization	81.1 ± 3.9	77.6 ± 5.6	92.3 ± 17.7	88.5 ± 6.2
% mortality	22.2 ± 6.3	19.1 ± 4.6	7.7 ± 2.1	6.9 ± 1.7
% CR	13.1 ± 3.2	7.6 ± 7.1	9.9 ± 2.4	2.7 ± 0.6
% SK	18.1 ± 6.3	11.4 ± 3.8	2.0 ± 0.6	1.0 ± 0.4
% FF	6.0 ± 2.4	2.9 ± 0.8	2.6 ± 1.0	1.2 ± 0.5
% ED	22.4 ± 8.5	7.8 ± 2.2	1.3 ± 0.7	0.9 ± 0.5

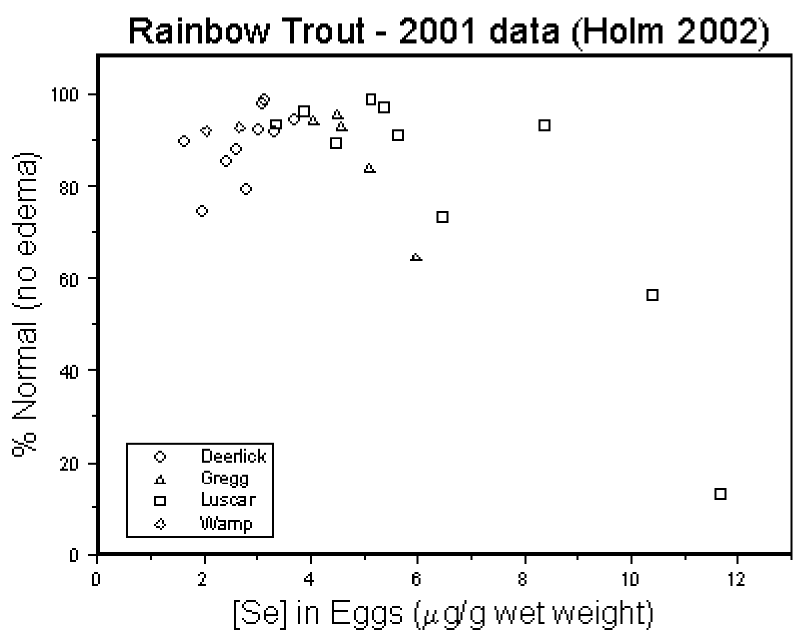
[a] number of fry to reach the swim-up stage
CR = craniofacial defects, SK = skeletal defects, FF = finfold defects, ED = edema,



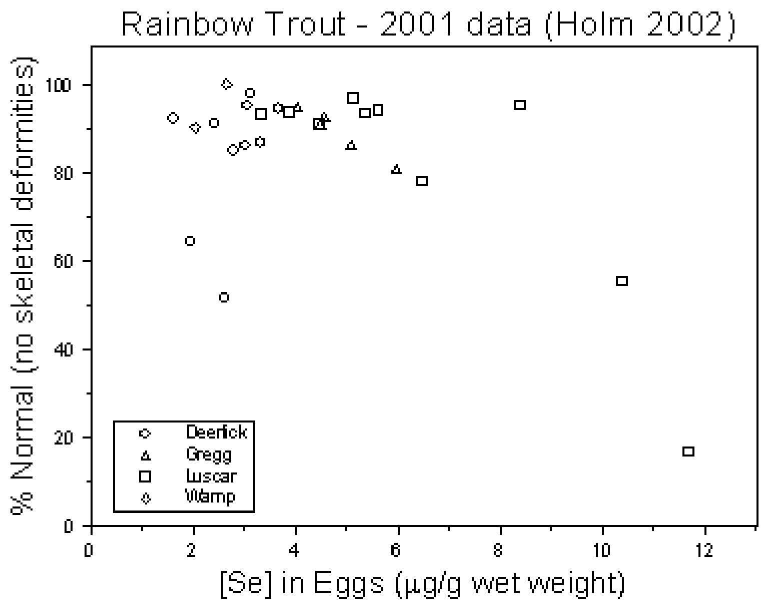
Holm Figure 1. Plot of percent normal (100 - percent edematous) against selenium concentration in adult rainbow trout muscle ww.



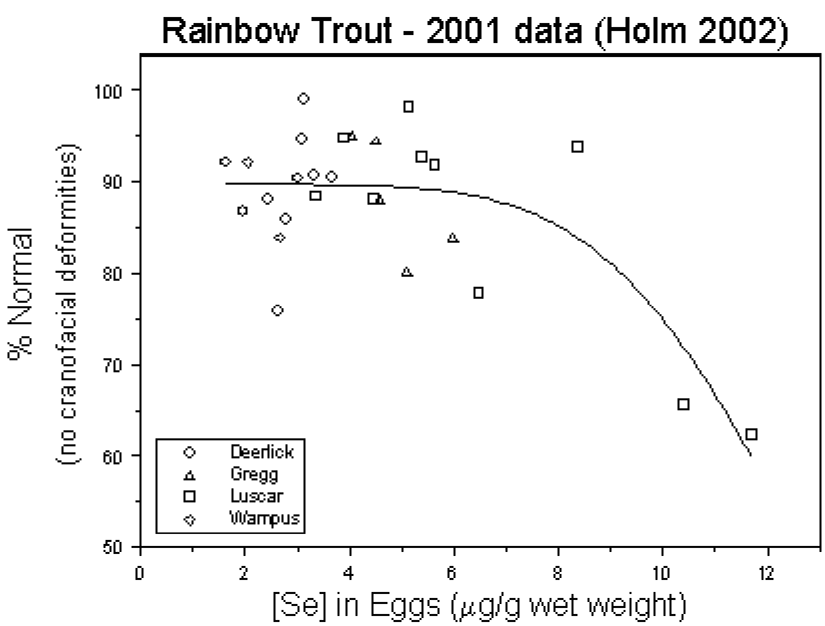
Holm Figure 2. Plot of percent normal (100 - percent total deformities) against selenium concentration in adult rainbow trout muscle ww, 2000 data.



Holm Figure 3. Plot of percent normal (100 - percent total deformities) against selenium concentration in rainbow trout eggs ww, 2001 data.

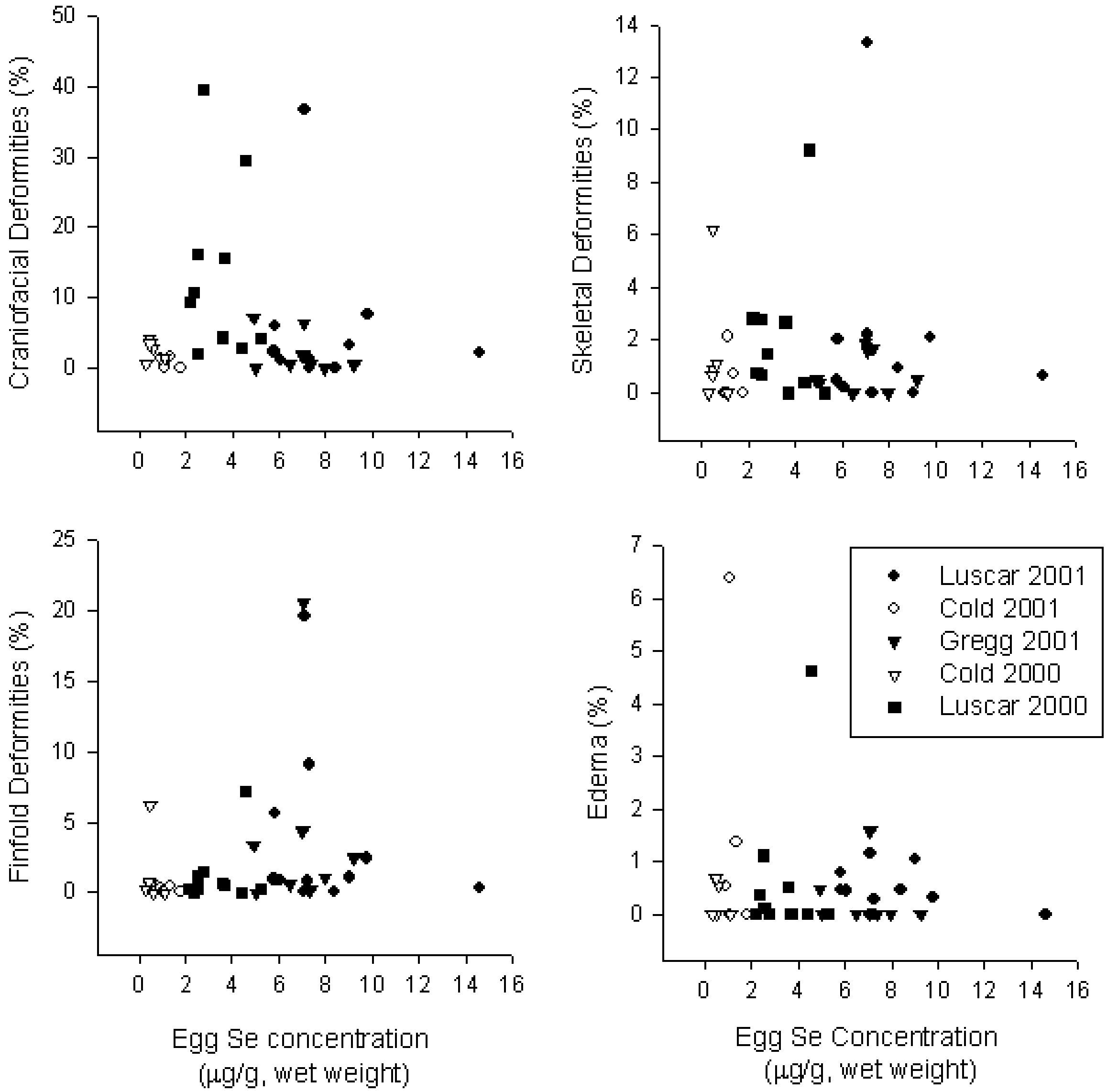


Holm Figure 4. Plot of percent normal (100 - percent skeletal deformities) against selenium concentration in rainbow trout eggs ww, 2001 data.



Holm Figure 5. Plot of percent normal (100 - percent total deformities) against selenium concentration in rainbow trout eggs ww, 2001data. EC_{20} value at 10.4 µg Se/g egg ww.

Brook Trout - 2000 and 2001



Holm Figure 6. Plot of percent normal (100 - total abnormalities) for craniofacial, skeletal and finfold deformities and edema against selenium concentration in brook trout eggs ww, 2000 and 2001 data.

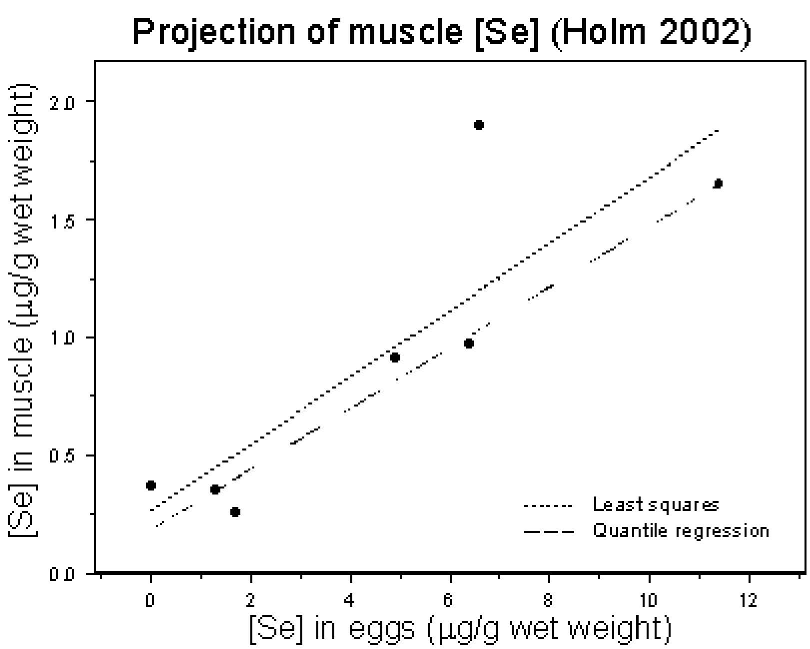
The effect levels determined using the *between streams* or *within streams* approach resulted in values based on ww in eggs or muscle. Several conversions were necessary to transform a selenium concentration in egg ww to whole body dw. Using data reported by Holm et al., quantile regression was used to estimate selenium in adult muscle (ww) from selenium in egg (ww) (see Projection of Muscle Selenium Concentrations below). A percent moisture of 75.84% derived from rainbow trout data was used to convert ww to dw and equation 1 was used to convert muscle dw to the whole body dw values listed below (under Chronic Values).

Projection of Muscle Selenium Concentrations

Median concentrations of selenium in rainbow trout muscles were projected from selenium concentrations in rainbow trout eggs according to an empirical equation:

$$[Se_{muscle}] = 0.1827 + 0.1287[Se_{egg}] \qquad (R = 0.6244, 5\ df)$$

Parameters of the linear model were estimated by quantile regression, which minimizes the sum of weighted absolute deviations. Such method is less sensitive to outliers than ordinary least squares (Koenker and Portnoy 1996). This difference is clearly illustrated in Holm Figure 7: projections of selenium concentrations in muscles of rainbow trout by the least squares regression line are consistently greater than projections by the quantile regression line ($[Se_{muscle}] = 0.2613 + 0.1418[Se_{egg}]$) due to the disproportional influence of one data point (6.6,1.9).



Holm Figure 7. Regression lines projecting selenium concentrations in muscles of rainbow trout as a function of selenium concentrations in rainbow trout eggs.

Chronic Values:

Between streams approach

Rainbow trout 2000: effects (craniofacial, skeletal and finfold deformities and edema) at 1.50 µg Se/g muscle ww or 5.79 µg Se/g dw whole body using conversion factors listed above; **chronic value is 5.79 µg Se/g dw whole body**

Brook trout 2000: effects (craniofacial deformities) at 3.79 µg Se/g muscle ww or 13.2 µg Se/g dw whole body using conversion factors listed above; **chronic value is 13.2 µg Se/g dw whole body**

Rainbow trout 2001: no effects at 6.65 µg Se/g egg ww or 4.14µg Se/g dw whole body using conversion factors listed above; **chronic value is >4.14 µg Se/g dw whole body**

Brook trout 2001: effects (finfold deformities) at 6.88 µg Se/g egg ww or 12.4 µg Se/g dw whole body using conversion factors listed above; **chronic value is 12.4 µg Se/g dw whole body**

Within streams approach

Rainbow trout 2000: **no value available**; EC_{20} analysis not appropriate for data sets

Brook trout 2000: **no value available**; EC_{20} analysis not appropriate for data sets

Rainbow trout 2001: EC_{20} value (craniofacial deformities) at 10.4 µg Se/g egg ww or 5.85 µg Se/g whole body dw; **chronic value is 5.85 µg Se/g whole body dw**

Brook trout 2001: **no value available**; EC_{20} analysis not appropriate for data set

Kennedy, C.J., L.E. McDonald, R. Loveridge, M.M. Strosher. 2000. The effect of bioaccumulated selenium on mortalities and deformities in the eggs, larvae, and fry of a wild population of cutthroat trout (*Oncorhynchus clarki lewisi*). Arch. Environ. Contam. Toxicol. 39:46-52.

Test Organism: Cutthroat trout (*Oncorhynchus clarki lewisi*; spawning adults, 3-6 years)

Exposure Route: dietary and waterborne - field exposure
Total selenium concentrations measured at the time the eggs were taken were <0.1 µg/L from the reference site and 13.3 to 14.5 µg/L at the exposed site.

Study Design: At reference and exposed site (Fording River, BC, Canada which receives drainage from open-pit coal mining), eggs were stripped from females (n=20 from reference site; n=17 from exposed site) and fertilized from milt from one male collected at each site. Fertilized eggs were reared in well water and examined for time to hatch, deformities (craniofacial, finfold, skeletal and yolk sac malformations), and mortalities. Inspection of deformities in eggs were performed using 40X magnification.

Effects Data : No significant correlations between the selenium concentrations in the eggs from either site and: hatching time (reference, 25.5-26.5 days; exposed, 22-25.5 days); percent deformities preponding (reference, 0-2.4%; exposed, 0-0.34%); percent deformities after ponding (reference, 0-0.26%; exposed, 0-0.09%); percent mortalities preponding (reference, 1.5-70.3%; exposed, 1-100%); percent mortalities after ponding (reference, 0.3-4.3%; exposed, 1.5-43.7%); total percent mortalities (reference, 2.8-55.8%; exposed, 3.7-100%). The average selenium residue in tissues were as follows:

Site	Adult fish liver, µg Se/g dw	Adult fish muscle, µg Se/g dw	eggs, µg Se/g dw
reference	8.2; Range: 3.4-14.6	2.4; 1.4-3.8	4.6
exposed	36.6; Range:18.3-114	12.5; Range: 6.7-41	21.2

Effects >12.5 µg Se/g dw in muscle

Chronic Value: >10.92 µg Se/g dw estimated using the equation I to convert the selenium concentration in muscle tissue (>12.5 µg Se/g dw) of adult fish to a selenium concentration in whole-body.

Hardy, R.W. 2002. Effects of dietary selenium on cutthroat trout (*Oncorhynchus clarki*) growth and reproductive performance. Annual report for Montgomery Watson Harza. April 30, 2002.

Test Organism: Cutthroat trout (*Oncorhynchus clarki*, 0.9 g)

Exposure Route: Dietary only
Six experimental dietary treatments were produced by cold extrusion. The formulation of the diet was designed to be similar to commercial trout diets and had a proximate composition of 45% protein and 16% lipid. Seleno-methionine diluted in distilled water (100 ug/L) was added in appropriate volumes to each batch of feed to facilitate pelleting. Measured dietary selenium concentrations were 1.2 (control), 3.8, 6.4, 9.0, 11.5, and 12 ug Se/g dw. Fry were fed initially at a rate of 10 times per day 6 days a week to apparent saturation. Feeding frequency decreased as fish grew.

Test Duration: 124 weeks (865 days, 2.5 yrs)

Study Design: Groups of 50 fish were placed into triplicate tanks (145 L) receiving 4-15 L/min of hatchery water at 14.5°C and fed one of the six experimental diets. The fish in each tank were bulk-weighed and counted every 14 days for the first 12 weeks of the experiment, and then every 4 weeks until 48 weeks. Samples of fish for whole-body selenium analysis were taken at each sampling date for the first 12 weeks followed by every 3 months thereafter. After six months of feeding, the fish were transferred to 575 L tanks and the number of replicate tanks per dietary treatment was reduced to two. After 80 weeks of feeding, the fish were transferred to 1050 L outdoor tanks each supplied with 70 L/min of constant temperature (14.5°C) spring (hatchery) water. After 2.5 years of the feeding trial, fish were spawned and whole body selenium level , egg selenium level, % eyed eggs, % hatched eggs, and % deformed larvae were examined.

Effects Data : No signs of toxicity (reduced growth or survival relative to controls) were observed in fish fed the highest dietary selenium treatment (12 ug Se/g dw) after the first 80 weeks of exposure just prior to transfer outdoors. No signs of clinical disease were evident, and no relationship was found between feed conversion ratios and the level of selenium added to the feed. Whole body selenium levels were approximately 6.8, 10, 12 and 12.5 ug Se/g dw in the four highest dietary treatments. Nine months later, whole body selenium levels at spawning had decreased somewhat to 5.21, 8.80, 9.37 and 6.66 ug Se/g dw in these four highest dietary treatment groups, respectively. Percent survival from the eyed stage to hatching varied among treatment groups, with the control having the highest survival (97%) and the fifth dietary treatment group the second highest (93%). Percent deformed larvae ranged from a low of 3.4% in controls to a high of 30% in the 9.0 ug Se/g dw dietary treatment group; larvae in the two highest dietary treatment groups only exhibited 7 and 6.8 %, respectively.

Chronic Value: The chronic value for this study is a NOAEC of >9.37 ug Se/g dw whole-body parent tissue based on embryo/larval deformity.

Bennett, William N., Arthur S. Brooks, and Martin E. Boraas. 1986. Selenium uptake and transfer in an aquatic food chain and its effects on fathead minnow larvae. Arch. Environ. Contam. Toxicol. 15:513-517.

Test Organism: Fathead minnow (*Pimephales promelas*; 2 to 8 day-old larvae).

Exposure Route: Dietary only
Green alga, *Chlorella pyrenoidosa* were exposed to Se ($H_2{}^{75}SeO_4$) in culture water for 3 days. Rotifers, *Brachionus calyciflorus*, were cultured in chambers with selenium containing green algae at the ratio of 25 µg algae/ml to 50 µg rotifer/ml for 5 hr. The rotifers were filtered to separate them from the algae and immediately heat-killed. The Se concentration in the rotifers was measured for ^{75}Se activity.

Test Duration: 9 to 30 days

Study Design: Selenium uptake by larval fathead minnows was measured in three experiments. Se-contaminated and control rotifers for feeding to larval fish were prepared in advance using the low algae:rotifer ratio. Daily equal volumes of rotifers were divided among five 800 mL polypropylene larval chambers. Three chambers received Se-contaminated rotifers and two received control rotifers. The rotifers were dead at the time of feeding (heat killed).

Larval fish were hatched from eggs spawned in the laboratory. After hatching, active larvae were divided equally among the larval test chambers (daily renewal exposures using declorinated Lake Michigan water). Larvae were initially fed rotifers raised on control algae (no selenium). The age of the larvae when first fed Se-contaminated rotifers was 4, 9, and 3 days post-hatch for experiments 1, 2, and 3, respectively. Larval fish were fed Se-contaminated rotifers for 7, 9, and 7 days in the 3 experiments. A post-exposure observation period of 19 and 2 days was used for experiments 1 and 2, respectively. During this time the larvae were fed control rotifers. Daily, larvae from a replicate were removed from the test chamber, washed, placed in a 20 ml vial, and counted for ^{75}Se activity for 20 min. All larvae were then placed in test chambers with fresh food rations. At the end of the study all fish were individually dried and weighed.

	Experiment 1	Experiment 2	Experiment 3
Initial feeding of control diet (days)	3	8	2
Day Se diet first fed	4	9	3
Day Se diet last fed	11	17	9
Observation days on control diet	19	2	0
Age at study termination (days)	30	19	9

Effects Data:

	Experiment 1	Experiment 2	Experiment 3
Mean food Se concentration (µg/g)	>70	68	55
Food intake (µg rotifers/larva)	50	1330	1190
Initial larvae mean dry wt. at start of Se-laden food (µg)	90	400	100
Final larvae mean dry wt. (µg) at end of test	1470 (Control) 800 (Treatment)[a]	1888 (Control) 1354 (Treatment)[a]	475 (Control) 416 (Treatment)
Final mean larval Se content (µg Se/larva)[b]	0.0062	0.0700	0.0248
Final mean larval Se concentrations (µg Se/g dw)	43.0	51.7	61.1

[a] Significantly different from the control.
[b] Values when Se-laden feeding was ended.

Selenium was measured in the test water during the feeding exposures, but the concentrations were insignificant (0.84 µg/L). Survival was not affected by the selenium exposures. Preliminary tests showed that fathead minnow larvae would reach plateau concentrations of selenium within the 7- to 9-day exposure periods. The food supply was sufficient to sustain growth of the larvae during the study, according to the authors. The authors state that selenium uptake and higher selenium content in experiment 2 larvae was due to their larger size and ability to consume more rotifers/unit time. Se-exposed larvae were significantly smaller ($p<0.05$) in mass than controls for experiments 1 and 2.

Chronic Value: The estimated whole-body chronic value for this study, determined as the geometric mean of the final mean larval selenium concentrations measured in the three experiments, i.e., 43.0, 51.7, and 61.1 µg/g dw, respectively, is 51.40 µg Se/g dw.

Ogle, R.S. and A.W. Knight. 1989. Effects of elevated foodborne selenium on growth and reproduction of the fathead minnow (*Pimephales promelas*). Arch. Environ. Contam. Toxicol. 18:795-803.

Test Organism: Fathead minnows (*Pimephales promelas*; juvenile, 59 to 61 d old)

Exposure Route: Dietary only
Purified diet mix spiked with inorganic and organic selenium: 25 percent selenate, 50 percent selenite, and 25 percent seleno-L-methionine, homogenized in dextrin.

Test Treatments: Completely randomized block design (2 blocks); 4 replicates per block (n = 8 replicates total per treatment). Actual mean total selenium levels in each exposure treatment were: 0.4 (control), 5.2, 10.2, 15.2, 20.3, and 29.5 µg/g dw. Fish used in the first randomized block (F_2 generation fish) were progeny from F_1 generation originally obtained from the Columbia National Fishery Research Laboratory, some of which were used in an initial range-finding experiment. Fish obtained from a commercial supplier were used in the second randomized block. The prepared diet was extruded into 1.5 mm pellets which were air-blow dried to 5 percent moisture content and crushed and sieved so that only particles retained by an 11.8 mesh/cm sieve were used in the study. The amount of selenium in water that leached from the food during the experiment averaged only 0.8 µg/L.

Test Duration: 105 days, F_2 generation (block one) and commercial fish (block two);
14 days F_3 generation

Study Design: Ten fish were randomly placed in each cell per block (n = 8x10, or 80 fish total per treatment). Fish were fed twice daily at 6 percent body weight per day, with wastes and uneaten food removed 30 min. after each feeding. Test tanks were flushed with two tank volumes of fresh test water after each feeding (solution renewal). Growth (as wet weight) was determined every two weeks by bulk weighing, and one fish from two of the cells per treatment in a given block (n = 4 total per treatment) was removed for selenium (whole-body) analysis. After 105 days of exposure, a single male and female fish from each treatment replicate (n = 4 breeding pairs per treatment in a given block, or 8 breeding pairs per treatment total) were placed in 250 ml beakers and inspected for spawning activity for 30 days following the first spawning event for that pair (each pair being one replicate). Gonads and muscle tissue were dissected for selenium analysis from these fish at the end of the 30 days spawning period. The spawning substrates were inspected daily for eggs to determine fertility and viability. Samples of not more than 50 eggs from each spawn were incubated in flowing, aerated water and inspected for percent hatch determination. Ten larvae from each incubated brood were transferred to separate glass test chambers and maintained (48 h renewal; fed brine shrimp twice daily) for 14 days to determine percent larval survival.

Effects Data: There was no effect of selenium on any of the reproductive parameters measured at the dietary concentrations tested. Percent hatch and percent larval survival were very high (>87.4 percent) and essentially equal for all of the treatments.

Growth of pre-spawning adults was affected by the selenium exposure. Growth data are given in the following table:

Effects on Fathead Minnow Growth after 98 days of Exposure to Dietary Selenium		
Measured mean selenium in diet, µg/g dw	Whole-body selenium, µg/g dw	Mean fish weight, g ww
0.4	1.76	1.30
5.2	2.78	1.24
10.2	3.42	1.20
15.2	5.40	1.21
20.3	6.58	1.09
29.5	7.46	0.94

Chronic Value: An EC_{20} value could not be calculated for these data because the data did not meet the minimum requirements for analysis. The MATC for growth of pre-spawning fathead minnows versus levels of selenium found in whole-body tissue was the GM of 5.40 and 6.58 µg/g dw, or 5.961 µg Se/g dw.

Schultz, R. and R. Hermanutz. 1990. Transfer of toxic concentrations of selenium from parent to progeny in the fathead minnow (*Pimephales promelas*). Bull. Environ. Contam. Toxicol. 45:568-573.

Test Organism: Fathead minnow (*Pimephales promelas*; Adults)

Exposure Route: Dietary and waterborne
Selenite was added to artificial streams which entered the food web; thus, fish were also exposed to selenium in the diet.

Study Design: Four Monticello artificial streams were used for the study which lasted from September 1987 to September 1988. For each study, two streams (treated) were dosed continuously to achieve 10 µg/L and two streams served as controls. Mean selenium concentrations at the head of the treated streams were 9.8 ± 1.2 and 10.3 ± 1.7 µg/L, respectively. The concentrations of selenium measured in the water from controls streams were all less than the detection limit, i.e., 2 µg/L. Spawning platforms were submerged into each stream. One subset of six embryo samples (n = 2000 embryos per sample) were collected from the streams for selenium analysis. Another subset of ten embryo samples were reared in incubation cups receiving the same streamwater dosed with sodium selenite via a proportional diluter. The treated embryos in egg cups received an average 9.7 ± 2.6 µg of selenium/L. Samples of hatched larvae were analyzed for selenium content while others were inspected for occurrence of edema and lordosis. Prior to test termination, female parents were seined. The mean selenium content in the ovaries of seven to eight females from the treated and control streams was reported.

Effects Data : Edema and lordosis occurred in approximately 25 percent of the fish spawned and reared in 10 µg of selenium/L. Corresponding occurrence in control fish incubated in the egg cups was only 1 and 6 percent, respectively. Selenium residues in the ovaries of females from the control and treated streams were 0.77 and 5.89 µg/g ww. Assuming 85 percent moisture content in the ovaries (see Gillespie and Baumann below), these concentrations equate to 5.133 and 39.27 µg Se/g dw.

Chronic Value: <18.21 µg Se/g dw estimated using equation II to convert the selenium concentration in adult female ovaries (39.27 µg Se/g dw) to a selenium concentration in whole-body.

Beyers, D.W. and Sodergren, C. 2001a. Evaluation of interspecific sensitivity to selenium exposure: Larval razorback sucker versus flannelmouth sucker. Larval Fish Laboratory. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado.

Test Organism: Larval flannelmouth sucker (*Catostomus latipinnis*) and larval razorback sucker *(Xyrauchen texanus)*

Exposure Route: Dietary and waterborne - laboratory exposure (28-d early life stage) Continuous flow diluter supplied a range of aqueous test concentrations <1, 25.4, 50.6, 98.9, and 190.6 µg/L selenate. Well water was used as the dilution water. Across the range of aqueous exposure concentrations, each test chamber was fed the same daily ration of living rotifers containing selenium at <0.702, 1.35, 2.02, 4.63, and 8.24 µg/g dw, respectively. Rotifers accumulated selenium from algae (*Chlorella vulgaris*) exposed to 0, 25, 50, 100, and 200 µg/L selenate.

Study Design: Replicated (n=4) exposure beakers using a randomized, balanced 5x2 factorial design (1st factor - selenium; 2nd factor - species). Survival was monitored daily and growth measured at the end of the 28-day exposure. Selenium was measured in the larvae at the end of the 28-day exposure.

Effects Data : No survival effects were observed and there were no decreases in fish weight or length. Fish mass was found to increase as a function of selenium concentration.

Chronic Value: The chronic values for the flannelmouth sucker and razorback sucker were >10.2 and >12.9 µg Se/g dw, respectively, based on the concentrations of selenium measured in whole-body tissue of larval fish at the highest water and dietary selenium concentrations.

Beyers, D.W. and Sodergren, C. 2001b. Assessment of exposure of larval razorback sucker to selenium in natural waters and evaluation of laboratory-based predictions. Larval Fish Laboratory. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado.

Test Organism: Larval razorback sucker *(Xyrauchen texanus)*

Exposure Route: Dietary and waterborne - laboratory exposure (28-d early life stage)
Larvae were exposed in a daily static-renewal system to control water (reconstituted very hard) and site waters: De Beque, Orchard Mesa, North Pond diluted 50%, and North Pond. Each water type received either a control diet (rotifers) or a diet previously exposed to the site water (site food: rotifers fed algae exposed to respective site water).

Study Design: Replicated (n=4) exposure beakers using a randomized, balanced 5x2 factorial design (1^{st} factor - test water type; 2^{nd} factor - rotifers cultured in control water or in site water). Survival was monitored daily and growth measured at the end of the 28-day exposure. Selenium was measured in the larvae at the end of the 28-day exposure.

Effects Data : No survival effects were observed. There were no significant decreases in growth of fish exposed to both site water and site food compared to fish exposed to control water and control food. There was a significant increase in growth of fish exposed to site water and control food relative to fish exposed to control water and control food ($p<0.0001$). There were reductions in the growth of fish (14%) exposed to site water and site food compared to site water and control food ($p<0.0001$). Due to the lack of a dose-response relationship in both the concentration of selenium in the food (rotifers) and growth, and the concentration of selenium in the fish larvae and growth, the authors did not attribute the effect of site food on the growth of fish to selenium.

Chronic Value: The NOAEC for the razorback sucker larvae in the four site water types based on selenium in whole-body tissue were: De Beque >5.45 µg Se/g dw; Orchard Mesa >11 µg Se/g dw; North Pond 50% dilution >41.1 µg Se/g dw; North Pond >42 µg Se/g dw. Because no significant effects were observed in larvae exposed to North Pond water at >42 µg Se/g dw whole-body tissue, this value was selected as the chronic value for the study.

Bryson, W.T., W.R.Garrett, M.A. Mallin, K.A. MacPherson, W.E. Partin, and S.E. Woock. 1984. Roxboro Steam Electric Plant 1982 Environmental Monitoring Studies, Volume II, Hyco Reservoir Bioassay Studies. Environmental Technology Section. Carolina Power & Light Company.

28-day Embryo/Larval Study

Test Organism: Bluegill sunfish (*Lepomis macrochirus;* embryos and larvae)

Exposure Route: dietary and waterborne - field exposure
Native adult bluegill were collected from Hyco Reservoir in Person County, North Carolina and from a nearby control lake (Roxboro City Lake). Hyco Reservoir is a cooling lake for Carolina Power & Light and receives the discharge from the ash storage pond. No selenium values were given for Hyco Reservoir, total selenium was not detected in the control lake (< 1 µg/L). A mean selenium for the ash pond effluent from a previous study was 53 µg/L (N=59; range 35-80 µg/L).

Study Design: All combinations of crosses between the Hyco and control fish were made using gametes from the collected fish. Fertilized eggs were exposed in egg cups to 0, 20 and 50 percent ash pond effluent under flow-through conditions. Percent hatch and swim-up success were measured. Swim-up larvae were released to exposure tanks where there were fed zooplankton collected from Hyco and the control lake. Larvae were observed for 28 days at which time survival and weight were measured.

Effects Data : Survival to the swim-up stage was different between larvae from Hyco females fertilized with either male type and those larvae from control females fertilized with either male type. All crosses involving a Hyco female resulted in larvae exhibiting 100 percent mortality prior to reaching swim-up. Percent survival from hatch to 28 days for larvae from control females exposed to control water and fed control lake zooplankton was only 5 and 12 percent for the two replicates so no meaningful comparisons can be made to the different dilution exposures or diet exposure. The mean concentrations of selenium in the ovaries, female liver and female muscle were 49, 130, and 84 µg/g dw, respectively.

Effect level: < 49, <130 and < 84 µg Se/g dw in adult ovaries, liver and muscle, respectively

Chronic Value: <59.92 µg Se/g dw estimated using the equation I to convert the selenium concentration in the muscle of Hyco females (84 µg Se/g dw) to a selenium concentration in whole-body.

<u>Ingestion Study</u>

Test Organism: Bluegill sunfish (*Lepomis macrochirus*; 30-day old larvae)

Exposure Route: Dietary and waterborne - field exposed adults
Juvenile bluegill from crosses with females in 0, 20 and 50 percent ash pond effluent were transferred to control water and fed zooplankton from either Hyco or the control lake. Selenium in Hyco and control zooplankton was 45 and 1.9 µg/g dw, respectively. Duration was not given.

Study Design: Survival and observations on pathology and morphology were made in the two diet treatments.

Effects Data: Mortality in larvae fed control zooplankton was 23.7 percent, whereas mortality in larvae fed Hyco zooplankton was 97.3 percent. There were no differences in survival (for two diet treatments) in larvae that were raised for the 30 days prior to the test in different effluent concentrations (0, 20 50 percent). The average selenium concentrations in the larvae fed control and Hyco zooplankton were 1.9 and 24.7 µg/g dw, respectively.

Effect level for larval survival: <24.7 µg Se/g dw in larvae

Chronic Value: None recommended for larval tissue.

Bryson, W.T., W.R.Garrett, M.A. Mallin, K.A. MacPherson, W.E. Partin, and S.E. Woock. 1985a. Roxboro Steam Electric Plant Hyco Reservoir 1983 Bioassay Report. Environmental Services Section. Carolina Power & Light Company. September 1985.

28-day Embryo/Larval Study

Test Organism: Bluegill sunfish (*Lepomis macrochirus*; embryos and larvae)

Exposure Route: dietary and waterborne - field exposed
Resident adult bluegill were collected from Hyco Reservoir in Person County, North Carolina and from a nearby control lake (Roxboro City Lake). Hyco Reservoir is a cooling lake for Carolina Power & Light and receives the discharge from the ash storage pond. For embryo/larval study up to swim-up stage, control fish were collected from the unaffected portion of Hyco.

Study Design: Repeat of 1982 28-day Embryo/Larval Study. Three crosses between: Hyco female and Hyco male; control female with Hyco male; and control female with control male. Gametes were fertilized and maintained for the 28-day test in ash pond effluent dilutions of 0, 20 and 50 percent. Percent hatch, percent swim-up success and survival were measured to 28 days post hatch. Two treatments were replicated and fed zooplankton collected from Hyco-affected and Hyco-unaffected (control). Larvae were observed for 28 days at which time survival and weight were measured.

Embryo/Larval Study up to Swim-up Stage. Five crosses were made between fish collected from the affected and unaffected areas. Percent hatch, percent swim-up and survival were measured until swim-up (approximately 3-4 days after hatch).

Effects Data : 28-day Embryo/Larval Study. All larvae that hatched from eggs obtained from Hyco females died prior to completing swim-up (see table below).

Effect level (larval survival): < 30, < 33 and < 59 µg Se/g dw for adult female bluegill in ovaries, liver and muscle, respectively

Summary of 28-day embryo larval study										
% effluent	parent source in cross M X F	% hatch	% swim-up	% survival, 28-days	adult tissue, µg Se/g dw					
					gonad		liver		muscle	
					M	F	M	F	M	F
0	H X H	92	0	0	33	30	43	33	62	59
20	H X H	98	0	0	33	30	43	33	62	59
20	H X H	92	0	0	33	30	43	33	62	59
50	H X H	97	0	0	33	30	43	33	62	59
0	H X C	89	87	18	33	2.2	43	4.4	62	2.7
20	H X C	96	96	34	33	2.2	43	4.4	62	2.7
50	H X C	60	84	58	33	2.2	43	4.4	62	2.7
0	C X C	79	95	40	nd	2.2	37	4.4	27	2.7
20	C X C	90	96	36	nd	2.2	37	4.4	27	2.7
20	C X C	88	97	25	nd	2.2	37	4.4	27	2.7
50	C X C	72	92	42	nd	2.2	37	4.4	27	2.7

Chronic Value: <43.70 µg Se/g dw estimated using equation I to convert the selenium concentration in the muscle of Hyco females (59 µg Se/g dw) to a selenium concentration in whole-body.

Embryo/larval study to swim-up. Percent swim-up of larvae from parents collected in non-affected Hyco averaged 93 percent, whereas percent swim-up from larvae collected from affected Hyco was 12 percent. Effect levels were determined for adult female and larval tissues. Larval tissues were averaged across effluent concentrations (geometric mean).

Effect level (percent swim-up):

Adult female ovaries: >9.1 µg/g dw; <30 µg/g dw
Adult female liver: >26 µg/g dw, <33 µg/g dw
Adult female muscle: >25 µg/g dw, <59 µg/g dw
Larvae: >12.8 µg/g dw; < 165 µg/g dw

Summary of Embyo/Larval Study up to Swim-up - Affected vs Unaffected Hyco											
date of fert.	Parents' capture location in Hyco	percent hatch			percent swim-up			selenium in tissue, µg/g dw			
		at % effluent			at % effluent			adult female			
		0	20	50	0	20	50	ovary	liver	musc	larvae
6-24	affected	93	98	94	0	0	0	30	33	59	0: 130 20: 120
6-27	affected	99	88	77	0	0	0	30	33	59	0: 130 20: 120
6-28	affected	29	34	35	25	14	3	30	33	59	0: 130 20: 120
6-28	affected	98	86	91	5	0	0	30	33	59	0: 130 20: 120
6-29	affected	88	93	85	59	42	25	30	33	59	0: 130 20: 120
7-14	unaffected	92	80	84	79	92	89	9.1	26	25	0: 19 20: 11 50: 10
7-26	unaffected	99	94	93	100	98	98	9.1	26	25	0: 19 20: 11 50: 10
7-27	unaffected	76	84	86	100	89	91	9.1	26	25	0: 19 20: 11 50: 10

Chronic Value: The chronic value estimated for the percentage larvae reaching the swim-up stage is presented as a range >25 µg Se/g dw in muscle tissue of Hyco females from the unaffacted area and >59 µg Se/g dw in muscle tissue of Hyco females from the affected area. Using equation I to convert the selenium concentration in the muscle of Hyco females to a selenium concentration in whole-body these values become >20.29 µg Se/g dw and <43.70 µg Se/g dw, respectively.

Bryson, W.T., K.A. MacPherson, M.A. Mallin, W.E. Partin, and S.E. Woock. 1985b. Roxboro Steam Electric Plant Hyco Reservoir 1984 Bioassay Report. Environmental Services Section. Carolina Power & Light Company

Ingestion Study

Test Organism: Bluegill sunfish (*Lepomis macrochirus;* juvenile- hatchery raised)

Exposure Route: Dietary only

Test Treatments: 5 diets: Se form (nominal selenium concentration in base diet)
seleno-DL-cystine (5 µg/g)
seleno-DL-cystine (10 µg/g)
seleno-DL-methionine (5 µg/g)
sodium selenite (5 µg/g)
Hyco zooplankton (5 µg/g)

Test Duration: 60 days

Study Design: Each treatment contained 40 fish which were maintained in a flow-through system. Fish were fed at 3 percent of their body weight. Length and weight were measured on days 30 and 60. Total selenium was measured in liver and whole-body.

Effects Data: No decreased length or weight in any of the Se-diets relative to the control.

Chronic Value: all values are whole-body
seleno-DL-cysteine: >2.16 µg Se/g dw
seleno-DL-cysteine-2X: >3.74 µg Se/g dw
seleno-DL-methionine: >2.46 µg Se/g dw
sodium selenite : >1.21 µg Se/g dw
Hyco zooplankton: >2.35 µg Se/g dw

Because none of the selenium-spiked diet formulations affected growth of juvenile fish at the concentrations tested, the chronic value selected for this study is >3.74 µg Se/g dw for the seleno-DL-cysteine-2X formulation.

Source and Exposure Embryo-Larval Study

Test Organism: Bluegill sunfish (*Lepomis macrochirus;* Adults from Hyco and a control lake)

Exposure Route: dietary and waterborne - field exposure

Test Treatments: Four treatments:
Hyco–collected fish exposed to Hyco water in flow through spawning tanks.
Hyco-collected fish in control water in flow through spawning tanks.

Control fish exposed to Hyco water in flow through spawning tanks.
Hyco-collected fish in control water in flow through spawning tanks.

Test Duration: Adult fish were in spawning tanks 4-7 months

Study Design: Eggs from each treatment were observed for percent hatch and percent swim-up.

Effects Data: Fish collected from the control lake did not spawn. Percent hatch and percent swim-up from Hyco fish in Hyco and control water are given in the table below. The percent hatch and percent swim-up were >83 and >83 for all the Hyco fish suggesting no effect for these endpoints.

Source of parents	Se in parental liver tissue, µg/g dw	water type for eggs and larvae	N	percent hatch	percent swim-up
Hyco	18.6	Hyco	16	86.6	91.1
Hyco	18.6	well water	10	83.8	95.5
Control	13.8	Hyco	a	a	83.3
Control	13.8	well water	12	86.0	97.4

a percent hatch unknown.

Chronic Value: The chronic value for this study is >18.6 µg Se/g dw liver tissue, or >5.45 µg of Se/g dw whole body tissue using equation III.

Gillespie, R.B. and P.C. Baumann. 1986. Effects of high tissue concentrations of selenium on reproduction by bluegills. Trans. Am. Fish. Soc. 115:208-213.

Test Organism: Bluegill sunfish, wild-caught (*Lepomis macrochirus*; adults; embryos and larvae)

Exposure Route: dietary and waterborne - field exposure

Test Treatments: High selenium adult fish were collected (electrofishing and with Fyke nets) from Hyco Reservoir. Low selenium adult fish were collected from Roxboro City Lake, Roxboro, NC.

Study Design: All possible combinations of bluegill parents from Hyco Reservoir and Roxboro City Lake were artificially crossed in June and July, 1982 and 1983, respectively. Fertilization success was assessed by stripping subsamples of 100 to 500 eggs per female and combining them with 2 ml of sperm. All zygotes were reared in Roxboro City Lake water and percent fertilization was estimated 2-3 hours later as the proportion of mitotically active zygotes. To estimate hatching success, gametes were combined as before and subsamples of 100 to 300 embryos per cross were transferred to egg cups and maintained in closed aquaria receiving recirculated Roxboro City Lake water. Percent hatch (approx. 2d at 22 to 25ºC) was based on the number of yolk-sac larvae.

In 1982, about 200 embryos from 8 crosses were observed and preserved at intervals up to 40 h afer fertilization, and about 450 larvae were preserved at intervals of 40 to 180 h after fertilization. In 1983, about 1,800 larvae were observed and preserved from 40 to 150 hr from crosses involving females from Hyco Reservoir, and about 40-300 hr for crosses involving females from Roxboro City Lake (10 crosses total).

Effects Data: No significant differences were found in percent fertilization or in percent hatch among parent combinations from the 18 crosses made in June 1982 and July 1983. In contrast, larvae from all crosses involving a Hyco female were edematous; 100 percent of the larvae were abnormal in 7 of 8 crosses. Note: This outcome was observed when the same female from Hyco Reservoir was crossed with males from either Hyco Reservoir or Roxboro City Lake. The range of selenium concentrations in the ovaries of Hyco Reservoir females used for the cross experiments was from 5.79 to 8.00 (GM = 6.945 µg/g wet weight; n=7). The reported concentrations of selenium in ovaries and carcasses of females collected from Hyco Reservoir in 1982 and 1983 were 6.96 and 5.91 µg/g wet weight (n=22 and 28, respectively). The reported concentrations of selenium in ovaries and carcasses of females collected from Roxboro City Lake in 1982 and 1983 were 0.66 and 0.37 µg/g wet weight (n=14 and 19, respectively). The mean selenium concentration in bluegill larvae (n=222) from artificial crosses of parents from Hyco Reservoir was 28.20 µg Se/g dw.

Chronic Value: <21.47 µg Se/g dw estimated using equation II to convert the selenium concentration in ovaries of Hyco females (46.30 µg Se/g dw; assuming 85 percent moisture content) to a selenium concentration in whole-body.

Coyle, J.J., D.R. Buckler and C.G. Ingersoll. 1993. Effect of dietary selenium on the reproductive success of bluegills (*Lepomis macrochirus*). Environ. Toxicol. Chem. 12:551-565.

Test Organism: Bluegill sunfish (*Lepomis macrochirus*; two-year old pond-reared adult fish and resultant fry)

Exposure Route: Dietary and waterborne
Dietary
Seleno-L-methionine added in an aqueous solution to Oregon moist pellets; moisture content of diet was 25 percent.
Waterborne
Flow through,10 µg Se/L nominal, 6:1 ratio of selenate:selenite, 98 percent purity, adjusted to pH 2 with HCl to prevent bacterial growth and change in oxidation states of Se(IV) and Se(VI).

Test Duration: 140 days

Study Design: The experiment consisted of a test control and food control (see Test Treatment table below) with fish (n=28 initially) in the four remaining treatments fed one of the four seleno-methionine diets in combination with 10 µg Se/L in water. Spawning frequency, fecundity, and percentage hatch were monitored during the last 80 days of the exposure period. Survival of resulting fry (n=20) was monitored for 30 days after hatch. Adults and fry were exposed in separate, modified proportional flow-through diluters. Fry were exposed to the same waterborne selenium concentrations as their parents. Adults were fed twice daily *ad libitum*. Whole-body selenium concentrations in adult fish were measured at days 0, 60, and were calculated from individually analyzed carcass and gonadal tissue (ovaries and testes) at day 140. Eggs not used in percentage of hatch determinations were frozen and analyzed for total selenium.

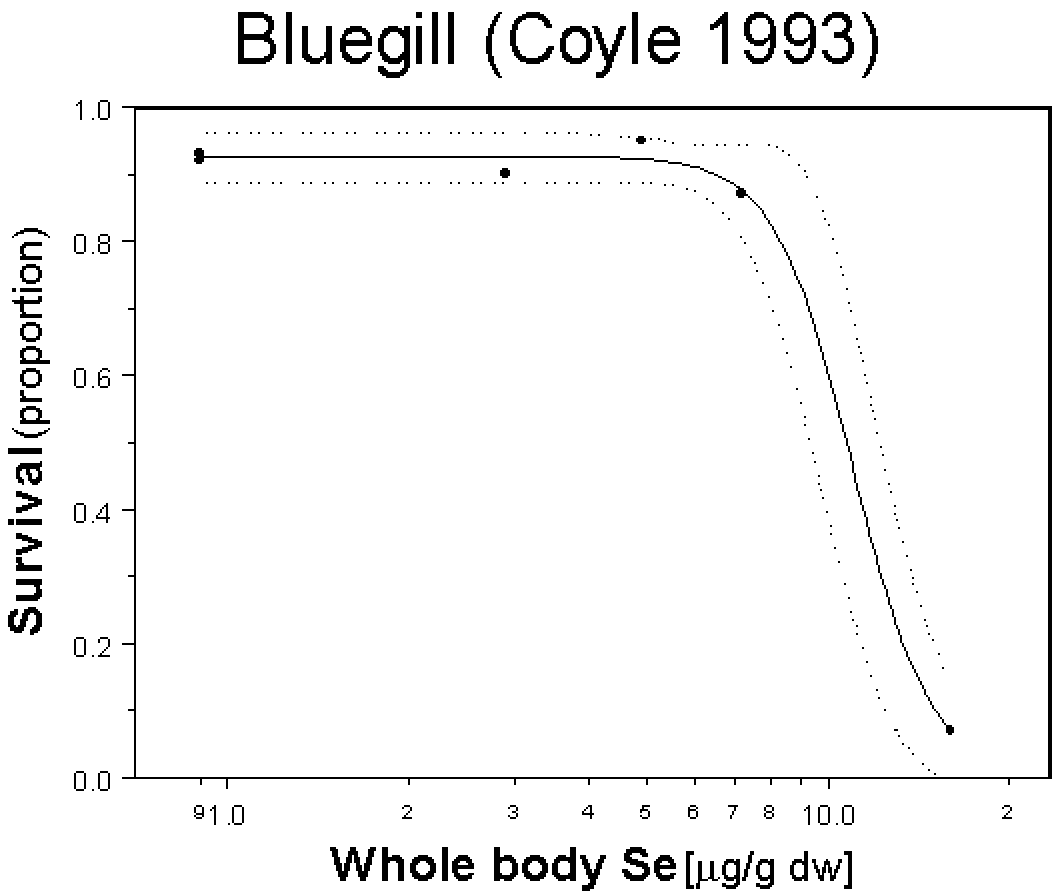
Measured Se in:	Test Treatments					
	1 (test control)	2 (food control)	3	4	5	6
water (µg Se/L)	0.56	8.4	10.5	10.5	10.1	11.0
diet (µg Se/g dw)	0.76	0.76	4.63	8.45	16.8	33.3

Effects Data: There was no effect of the combination of highest dietary selenium concentration (33.3 µg/g dw) in conjunction with exposure to a waterborne selenium concentration of 11.0 µg/L on adult growth (length and weight), condition factor, gonad weight, gonadal somatic index, or reproductive endpoints (i.e., spawning frequency, number of eggs per spawn, percentage hatch) during the 140-day exposure. The mean corresponding whole-body selenium concentration in adults exposed to this waterborne and dietary selenium combination was 19 µg/g dw. Survival of fry from the exposed adults was affected by 5 days post-hatch. Concentrations of whole-body selenium in adult tissue at day 60 were used to determine effects in the fry because eggs were taken for the larval tests beginning at day 60 of the adult exposure.

Effects on Adults						
Se in diet, µg/g dw	Se in water, µg/L	whole-body Se (140 d), µg/g dw	replicate	total no. spawns	eggs/spawn	hatchability, %
0.8	0.5	0.8	A	15	14,099	94.5
			B	10	5,961	90.5
0.8	7.9	1.0	A	12	9,267	89.5
			B	11	9,255	84.5
4.6	10.5	3.4	A	20	9,782	86.5
			B	12	13,032	96.5
8.4	10.5	6.0	A	2	10,614	96.5
			B	9	7,995	90
16.8	10.1	10	A	13	10,797	83
			B	13	9,147	91.5
33.3	10.1	19	A	14	8,850	80
			B	4	8,850	80

Effects on Larvae			
Se in diet, µg/g dw	Se in water, µg/L	adult whole-body (60 d), µg/g dw	mean survival, %
0.8	0.5	0.9	92
0.8	7.9	0.9	93
4.6	10.5	2.9	90
8.4	10.5	4.9	95
16.8	10.1	7.2	87
33.3	10.1	16	7

Chronic Value: The EC_{20} value calculated for survival of fry versus levels of selenium found in the eggs and whole-body tissue of adults after 60 d of exposure is 8.954 µg Se/g dw.



Bluegill (Coyle 1993)
1.0
0.8
0.6
0.4
0.2
0.0
Survival (proportion)
91.0
2
3
4
5
6
7
8
10.0
2
Whole body Se [µg/g dw]

Cleveland, L. et al. 1993. Toxicity and bioaccumulation of waterborne and dietary selenium in juvenile bluegill sunfish (*Lepomis macrochirus*). Aquatic Toxicol. 27:265-280.

Test Organism: Bluegill sunfish (*Lepomis macrochirus*)
Life Stage: juvenile (5 months - waterborne exposure; 3 months - dietary exposure)

Exposure Route: waterborne (60-d) and dietary (90-d) - separate exposures
waterborne - 6:1 selenate:selenite at 0.17, 0.34, 0.68, 1.38, 2.73 mg/L; dietary - seleno-L-methionine in Oregon moist at 1.63, 3.25, 6.5, 13, 26 µg Se/g dw)

Study Design: Fish were exposed using a flow-through diluter. Each test consisted of an exposure and a depuration phase. Whole body tissue measurements were made at 31 and 60 days of waterborne exposure and at 31, 59 and 90 days of dietary exposure. Mortality and condition factor, K (weight x 10^5/length^3), were measured at selected intervals.

Effects Data : The waterborne exposure (see table below) was determined to have an EC_{20} = 4.07 µg Se/g dw (1.96-8.44 µg/g 95% CL). However, because it was a water-only exposure, it was not considered in the derivation of the FCV.
A mortality effect level for the dietary exposure could not be calculated because the highest selenium whole body concentration (13.4 µg Se/g dw) only had 17.5% mortality. The middle selenium concentration did have 22.5% mortality. Cleveland et al. reported a significant decrease in K between 4.7 and 7.7 µg/g dw (see table below).

Waterborne Exposure Study

measured selenium in water (µg/L)	60-d measured selenium in whole body (µg/g dw)	60-d mortality (%)	condition factor (K)
20 (control)	1.1	10	1.5
160	2.8	12.5	1.5
330	4	22.5	1.6
640	5.3	52.5	1.5
1120	9.8	70	1.6
2800	14.7*	97.5	NA

*A 30-d measurement because all fish were dead at 60 days in this concentration.

Dietary Exposure Study

measured selenium in food (µg/g ww)	60-d measured selenium in whole body (µg/g dw)	60-d mortality (%)	condition factor (K)

0.68 (control)	1	5	1.3
2.3	2.1	7.5	1.3
3.5	3.3	10	1.3
6.6	4.7	22.5	1.3
12.7	7.7	15	1.2
25	13.4	17.5	1.2

Chronic Value: Given the very slight reduction in K (1.3 to 1.2) and the uncertain relevance of growth data, the NOAEC is interpreted to be 13.4 µg Se/g dw for this study; and the chronic value is >13.4 µg Se/g dw.

Lemly, A.D. 1993a. Metabolic stress during winter increases the toxicity of selenium to fish. Aquatic Toxicol. 27:133-158.

Test Organism: Bluegill sunfish (*Lepomis macrochirus;* juvenile 50-70 mm)

Exposure Route: Waterborne and dietary
Water
1:1 selenite:selenate in stock at pH 2; metered in to reach 5 µg/L
Diet
seleno-L-methionine in TetraMin (5 µg/g dw)

Test Duration: 180 days

Study Design: Fish were exposed (treatment and control) under intermittent flow-through conditions for 180 days. Tests were run at 4° and 20°C with biological (histological, hematological, metabolic and survival) and selenium measurements made at 0, 60, 120 and 180 days. Fish were fed at a rate of 3% body weight per day. All treatments were initiated at 20°C and then decreased in the cold treatment at a rate of 2°C per week for 8 weeks to reach 4°C and then maintained at that temperature for the remainder of the 180 days.

Effects Data : In the 20°C test, fish accumulated 6 µg/g dw selenium (whole-body) with no significant effect on survival (4.3% and 7.4% mortality in control and treatment, respectively). In the 4°C test, fish exposed to selenium accumulated 7.9 µg/g dw (whole-body) selenium and had significant mortality after 120 (33.6%) and 180 days (40.4%) relative to control (3.9%). Several hematological measurements were significantly different in both the warm and cold selenium exposures relative to controls. Both warm and cold selenium treatments also had greater O_2 consumption than controls. Fish lipid content in the cold Se treatment decreased more than the cold control; lipid content did not decrease in either the warm control or the warm Se treatment (see summary tables below). The results suggest significant mortality occurs in juvenile bluegill during winter months when tissue concentrations reach 7.91 µg/g dw and lipid levels decrease to 6 percent.

Chronic Value: 20°C, > 6 µg/g Se whole-body; 4°C, < 7.91 µg/g dw Se whole body

Mean Concentration of Selenium in Tissues, Cumulative Survival*, Percent Lipid Content and Oxygen Consumption in Juvenile Bluegill

day	cold - Se control				cold + Se				warm - Se control				warm + Se			
	Se[a]	Surv. %	lipid, %	O_2[b]	Se[a]	Surv. %	lipid, %	O_2[b]	Se[a]	Surv. %	lipid, %	O_2[b]	Se[a]	Surv. %	lipid, %	O_2[b]
0	1	100	13.2	98	1	100	13.2	98	1	100	13.2	98	1	100	13.2	98
60	1	97.1	12.5	58	5.8	92.9	10	63	1.2	95.7	13.3	98	5.8	100	13.3	103
120	1.1	97.1	11.5	57	7.9	66.4	6	81	1.1	95.7	13.4	100	6	96.7	13.4	120
180	1.4	97.1	10.5	57	7.9	59.6	6	78	1.2	95.7	13.6	100	6	92.6	13.5	120

a whole body Se tissue concentration, µg/g dw
b oxygen consumption, mg/kg/hr

* Cumulative Survival: In this experiment, 240 juvenile bluegill were placed in three 400-L fiberglass tanks, 80 in each, and exposed to each control and treatment for a period of 180 days. Ten fish were removed at random from each treatment replicate on days 0, 60, 120, and 180 for selenium, histological, hematological, and metabolic measurements.

Replicate and Average Whole-body concentrations (µg/g dry weight) of selenium in juvenile bluegill*

	day 0				day 60				day 120				day 180			
replicate	1	2	3	mean	1	2	3	mean	1	2	3	mean	1	2	3	mean
c+Se	0.87	1.21	0.95	1.01	6.30	5.49	5.76	5.85	8.36	7.31	7.85	7.84	7.53	8.01	8.19	7.91
w+Se	1.17	0.96	0.90	1.01	5.61	6.19	5.43	5.74	6.37	5.92	5.50	5.93	5.48	5.72	6.02	5.74
c-Se	0.89			0.89	0.97			0.97	1.01			1.01	1.10			1.10
w-Se	0.99			0.99	1.12			1.12	0.99			0.99	0.96			0.96

* Each value is for a composite sample made from 5 fish.

The Kaplan-Meier estimator was used to calculate survival at time t

$$\hat{S}(t) = \frac{\prod r(t_i) - d_i}{r(t_i)}$$

where $r(t_i)$ is the number of fish alive just before time t_i, i.e. the number at risk, and d_i is the number of deaths in the interval $I_i = [t_i, t_{i+1}]$. The 95% confidence interval for such estimate (Venables and Ripley 2002) was computed as

$$\exp\left\{-\hat{H}(t)\exp\left[\pm k_\alpha \frac{\text{s.e.}\left(\hat{H}(t)\right)}{\hat{H}(t)}\right]\right\}$$

where

$$\hat{H}(t) = \sum \frac{d_j}{r(t_j)} \qquad \text{and } j \le i$$

The following table lists the estimates of survival in the cold + Se treatment at 60, 120 and 180 days. The term n.event is the number of deaths at a given interval; n.risk is the number of organisms alive at the beginning of the interval; survival is computed by the Kaplan-Meier estimator.

Time	n.risk	n.event	survival	std.err	lower 95% CI	upper 95% CI
60	210	15	0.929	0.0178	0.884	0.956
120	165	47	0.664	0.0350	0.590	0.728
180	88	9	0.596	0.0381	0.517	0.666

Hematological Measurements in Juvenile Bluegill Sunfish (*indicates significantly different from control)

Warm Exposure	day 0		day 60		day 120		day 180	
blood parameter	warm-Se	warm+Se	warm-Se	warm+Se	warm-Se	warm+Se	warm-Se	warm+Se
total erythrocyte, 10^6/ml	2.95	2.92	2.96	2.93	2.99	2.95	2.96	2.89
% mature	85	86	86	93*	86	94*	85	94*
nuclear shadows, 10^4/ml	0.95	0.86	0.97	2.05*	0.83	2.38*	0.91	2.30*
total leucocytes, 10^4/ml	17.22	17.41	16.90	17.55	16.73	17.62	17.05	17.36
% lymphocytes	23	25	20	23	19	26	21	22
% neutrophils	15	13	14	15	17	19	17	16
hematocrit, %	37	36	37	29*	36	29*	38	28*
MCHC (mean corpuscular hemoglobin conc.)	23	25	25	19*	25	18*	25	17*
Cold Exposure	day 0		day 60		day 120		day 180	
blood parameter	cold-Se	cold+Se	cold-Se	cold+Se	cold-Se	cold+Se	cold-Se	cold+Se
total erythrocyte, 10^6/ml	2.91	2.93	2.97	2.90	3.01	2.95	3.00	2.99
% mature	84	82	87	95*	85	96*	85	97*
nuclear shadows, 10^4/ml	0.86	0.84	0.83	2.30*	0.89	2.49*	0.90	2.36
total leucocytes, 10^4/ml	16.48	16.88	16.79	16.91	16.80	16.74	16.96	16.63
% lymphocytes	17	16	16	17	19	15	19	18
% neutrophils	13	12	15	11	15	12	12	14
hematocrit, %	39	37	40	30*	41	28*	39	27*
MCHC (mean corpuscular hemoglobin conc.)	26	25	25	18*	22	17*	23	17*
MCV (mean corpuscular volume)	182	171	188	146*	180	135*	185	130*

Hermanutz et al. 1996. Exposure of bluegill (*Lepomis macrochirus*) to selenium in outdoor experimental streams. U.S. EPA Report. Mid-Continent Ecology Division. Duluth, MN.

Test Organism: Bluegill (*Lepomis macrochirus*; 3 to 4-year old adults)

Exposure Route: Dietary and waterborne followed by dietary only

Dietary and waterborne

Selenite was added to artificial streams which entered the food web; thus, fish were also exposed to selenium in the diet.

Dietary only

Recovering streams exposed bluegill to selenium in prey organisms. Selenite addition to water was ceased (selenium in water was below detection level).

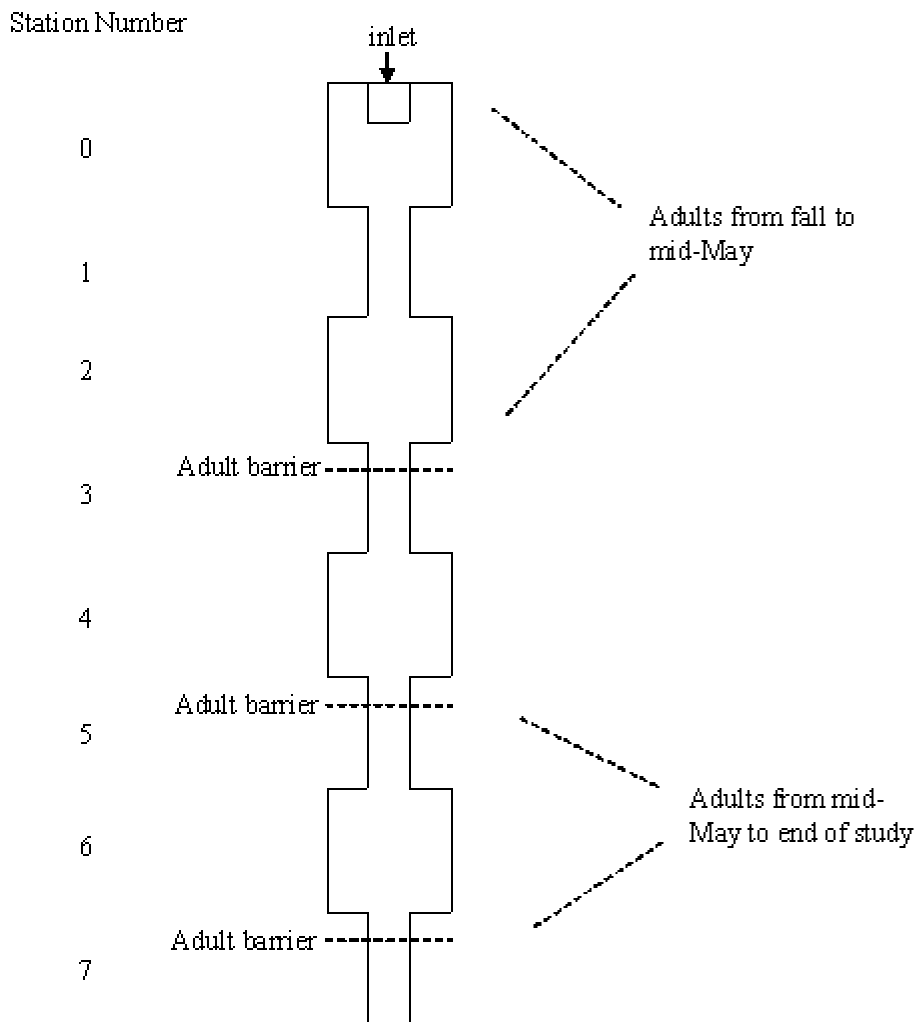
Study Design: Eight Monticello artificial streams were used for three separate studies between 1987 and 1990.

Stream	Study I	Study II	Study III
Dates BG[a] put in station 0-2 BG transferred to sta. 6 End of study	 9-1-87 5-16-88 8-22-88	 10-88 5-89 8-89	 11-89 5-90 7-90
1	Unused	Control	Control
2	Unused	2.5 µg/L	Recovering
3	10 µg/L	10 µg/L	Recovering
4	30 µg/L	Recovering	Recovering
5	Control	Control	Control
6	30 µg/L	Recovering	Recovering
7	Control	2.5 µg/L	Recovering
8	10 µg/L	10 µg/L	Recovering

[a] BG = Bluegill.

A schematic diagram of an artificial stream is provided below. For each study, a random sample of 22-50 adult bluegill were transferred from stations 0-2 (provided temperatures above 4°C during winter) to station 6 (most suitable for nests) during mid-May for spawning. Spawning activity was monitored in the streams. Embryo and larval observations were made *in situ* and in the laboratory from fertilized eggs taken from the streams and incubated in the lab.

Schematic Design of One of the Artificial Streams in the Monticello Study



Effects Data : Adult survival in Studies II and III was very low and will not be considered in the effects analysis. The percent hatch, percent larval survival, percent edema, percent lordosis and percent hemorrhaging in the 2.5 and 10 µg/L streams for Study II are provided in the table below. The values presented in this table are corrected values for Study II as reported by Tao et al. (1999). The data from Study II (both egg cup and field nest) were not amenable for regression analysis. As reported by Tao et al. (1999), ANOVA was utilized to evaluate effects of elevated concentrations of selenium on percent hatch, percent survival, maximum percent edema, lordosis, and hemorrhage, and minimum percent healthy (egg cup data). Treatment effects were only significant for maximum percent edema and minimum percent healthy (see their Table 4-19), and in no instance were differences between the 2.5 µg Se/L and control treatments significant (Dunnett's Means test, all probabilities > 0.1, see their Table 4-20). These results clearly suggest that the 2.5 µg Se/L treatment had no adverse impact on bluegill larvae. They are further supported by analysis of the field nest data (see table below). In this experiment, treatment had a significant effect on maximum percent edema (raw data and ranks) and maximum percent hemorrhage (ranks only). Probabilities of differences between the 2.5 µg Se/L and control treatments were >0.2 for all response variables except maximum percent hemorrhage, which had an estimated probability of 0.05 (raw data, P=0.022 for ranks; Dunnett's means test). Such values, though, were well above the adjusted experiment-wise error rate for multiple comparison (α'=0.0085, $\alpha'=1-(1-\alpha)^{1/k}$; α=0.05, k=6 comparisons; Sokal and Rohlf 1981), which takes into account the fact that selenium effects were tested on six different response variables. Therefore, the chronic value for this study, 12.12 µg Se/g dry weight, was calculated as the geometric mean of tissue concentrations of selenium in the 2.5 (NOAEC) and 10 µg Se/L (LOAEC) treatments (5.55 and 26.46 µg Se/g dw whole body tissue, respectively).

Chronic Value: 12.12 µg Se/g dw whole-body tissue, calculated as the GM of the NOAEC, 5.55 µg Se/g dw, and LOAEC, 26.46 µg Se/g dw, based on percent larval survival and percent larvae exhibiting edema in the egg cup exposures. Note: the NOAEC value of >17.35 µg Se/g dw was selected as the chronic value for Study III based on percent larval survival in egg cup exposures and percent larvae exhibiting edema in nest observations.

Effects on Progeny - Study II[a,b]

Egg cup observations								
treatment	stream	number of trials	% hatch	% survival to 3rd day	% edema	% lordosis	% hemorr	whole-body Se (µg/g dw)
control	1	6	93.0	75.2	0	0	0	2.05
control	5	5	96.4	71.5	0	0	0	1.85
2.5 µg/L	2	0	NA	NA	NA	NA	NA	6.8
2.5 µg/L	7	4	81.4	71.6	0	0	3.6	5.55
10 µg/L	3	3	83.3	57.7	100	11.1	49.3	20.75
10 µg/L	8	2	91.1	57.1	100	18.2	41.1	33.75
rec 30 µg/L	4	0	NA	NA	NA	NA	NA	NA
rec 30 µg/L	6	6	92.9	73.0	17.4	0	11.5	30.6

Nest Observations											
treatment	stream	# active nests	# embryos collected	% dead embryos	# larvae collected	% dead larvae	#samples w larvae	% edema	% lordosis	% hemorr	whole-body Se (µg/g dw)
control	1	6	2458	0.94	3252	0.03	7	0	0	0	2.05
control	5	9	1329	0	3435	1.05	13	0	0	0	1.85
2.5 µg/L	2	1	0		2497	0.20	3	4.1	25	77.6	6.8
2.5 µg/L	7	5	1462	0	4717	0.08	8	0	0	52	5.55
10 µg/L	3	2	672	0	5376	0.50	9	81.4	5.0	55.5	20.75
10 µg/L	8	3	931	0.32	750	0.40	4	50	14.7	26.7	33.75
rec 30 µg/L	4	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
rec 30 µg/L	6	8	646	0	6782	7.8	16	27.3	0	17.1	30.6

a Values in table were taken from Tao et al. (1999).

b The chronic value for the study was calculated as the GM of whole-body selenium concentrations in the 2.5 (NOAEC 5.55 µg Se/g dw; stream 7 only) and 10 µg Se/L (LOAEC of 26.46 µg Se/g dw; GM of streams 3 and 8, respectively) treatments in the egg cup exposures.

Effects on Progeny - Study III[a]

Egg cup observations								
treatment	Stream	number of trials	% hatch	% survival to 3rd day	% edema	% lordosis	% hemorr	whole- body Se (µg/g dw)
control	1	2	92	58.6	0	0	0	1.6
control	5	3	76.7	69.2	0	0.9	0.8	3.35
rec 2.5 µg/L	2	3	87.3	66	0	0	0	5.25
rec 2.5 µg/L	7	6	87.2	76.5	0	0	0	5.35
rec 10 µg/L	3							14.5
rec 10 µg/L	8	3	75.3	74.5	0	0	0	11.7
rec 30 µg/L	4	5	92	78				17.35
rec 30 µg/L	6							

Nest observations							
treatment	stream	# active nests	# samples with larvae	% edema	% lordosis	% hemorr	whole-body Se (µg/g dw)
control	1	2	5	0	0	0	1.6
control	5	2	3	0	0	0	3.35
rec 2.5 µg/L	2	5	5	0	0	0	5.25
rec 2.5 µg/L	7	5	2	0	0	0	5.35
rec 10 µg/L	3	2	4	0	0	0	14.5
rec 10 µg/L	8	4	4	0	0	0	11.7
rec 30 µg/L	4	9	13	0	0	0	17.35
rec 30 µg/L	6						

a The chronic value for the study was selected as the NOAEC of >17.35 µg Se/g dw from the recovering 30 µg Se/L treatment.

Coughlan, D.J. and J.S. Velte. 1989. Dietary toxicity of selenium-contaminated red shiners to striped bass. Trans. Am. Fish Soc. 118:400-408.

Test Organism: Striped bass (*Morone saxitilis*; adults from Lake Norman, NC, approximately 250 g each)

Exposure Route: dietary only
Treated fish were fed selenium contaminated red shiners (1 g) from Belews Lake, NC (9.6 µg Se/g ww or 38.6 µg Se/g dw based on a mean reported moisture content of 75.1 percent). Control fish were fed golden shiners from a local bait dealer (0.3 µg Se/g ww or 1.3 µg Se/g dw based on a mean reported moisture content of 76.3 percent).

Test Treatments: Test treatments were as described above. Two tanks contained treated fish (n = 20 fish total), and one tank of fish served as the control (n = 10 fish). Each tank received a continuous flow of soft well water (hardness and alkalinity approx. 30 mg/L as $CaCO_3$) throughout the exposure.

Test Duration: 80 days

Study Design: During the experiment, all striped bass (n = 10 per tank) were fed to satiation three times per day. Pre-weighed rations of live red shiners (treated fish) and golden shiners (controls) were added to the tanks and allowed 5 hours to feed. Uneaten prey was removed and weighed. Composite whole-body samples of each prey fish were collected at regular intervals throughout the study for whole-body tissue selenium analysis. The final selenium concentration in epaxial white muscle was determined for surviving striped bass at the end of the test. Moribund striped bass were sacrificed so as to obtain muscle tissue samples for selenium analysis. Samples of liver and trunk kidney of these and the surviving striped bass were dissected for observations of histopathology.

Effects Data: Striped bass fed selenium-laden red shiners exhibited changes in behavior (lethargy, reduced appetite), negligible weight gain, elevated selenium concentrations in muscle, histological damage, and death. Control fish ate and grew well, and behaved normally. Average selenium ingestion was between 60 and 140 µg Se/fish per day until day 30. Appetite of the treated fish appeared to be significantly reduced beyond this point compared to the appetite of the control group. By day 78, all striped bass fed the Se-laden red shiners either had died or were moribund and sacrificed for analysis. The final selenium concentration in muscle of treated striped bass averaged from 3.5 (tank 1) and 4.0 (tank 2) µg/g ww, or 17.5 and 20.0 µg/g dw, respectively, assuming 80 percent moisture content in muscle tissue. The final selenium concentration in muscle of control striped bass fed uncontaminated golden shiners averaged 1.1 µg/g ww, or 5.50 µg/g dw (assuming 80 percent moisture content in muscle tissue).

Chronic Value: The chronic value for percent survival of striped bass relative to final selenium in muscle tissue after being fed Se-laden red shiners is <17.50 µg/g dw, or 14.75 µg/g dw whole body tissue converted using equation I.

An EC_{20} value could not be calculated for this data set because the data did not meet the assumptions required for analysis.

Lemly, A.D. 1993b. Teratogenic effects of selenium in natural populations of freshwater fish. Ecotoxicol. Environ. Safety. 26: 181-204.

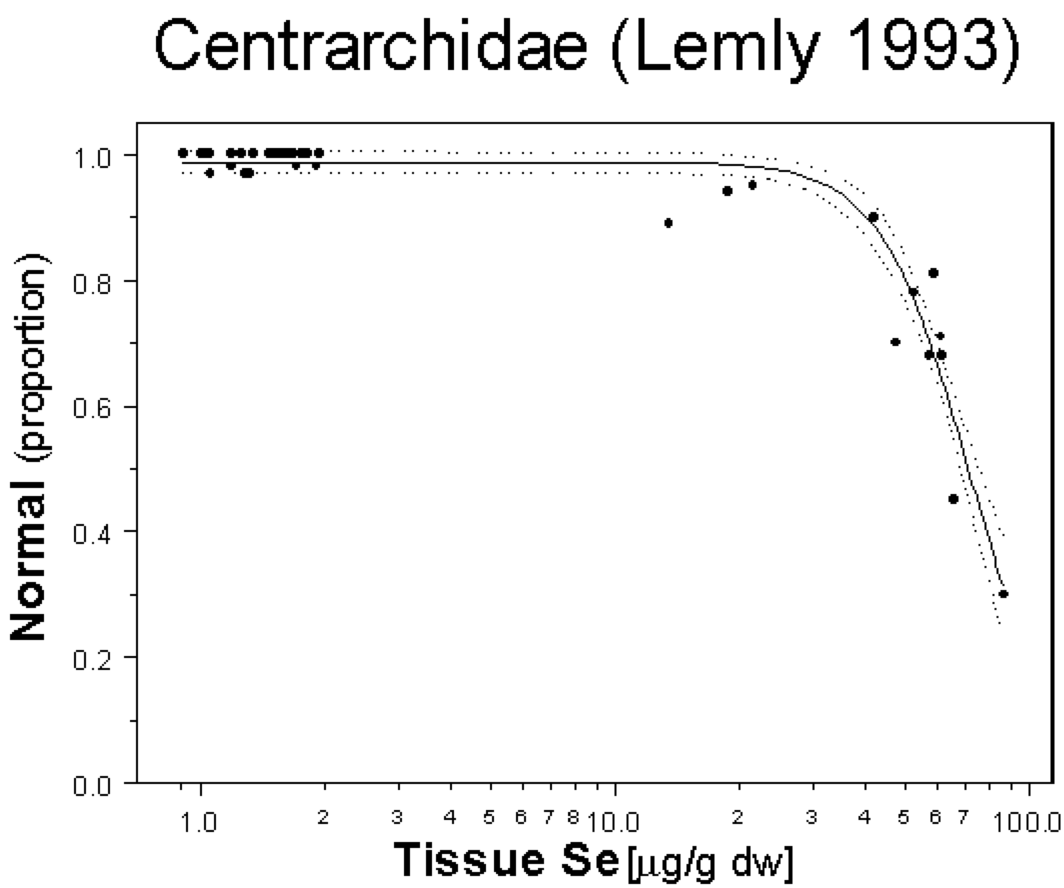
Test Organism: All possible fish species collected from Belews Lake and a reference site.

Exposure Route: dietary and waterborne - field exposed

Study Design: Surveys of external abnormalities in fish collected from Belews Lake and two reference lakes were done in 1975, 1978, 1982, and 1992. Five classifications of abnormalities were reported: (1) spinal deformities (lordosis, scoliosis, kyphosis); (2) accumulation of body fluid (edema, expothalmus or popeye); (3) missing or abnormal fins; (4) abnormally shaped head or mouth; and (5) cloudy eye lens or cornea (cataracts). Whole-body selenium was measured in each fish. The relationship between whole-body selenium and malformations was examined.

Effects Data : The relationship between whole-body selenium and the frequency of malformations in all the fish species collected at Belews (n=22) did not follow a clear trend. When evaluating only fish from the family Centrarchidae using a polynomial regression (cubic model) an R^2 value of 0.881 was obtained. Lemly reported that the inflection point where a rapid rise in deformities occurred was between 40 and 50 µg Se/g dw in whole-body tissue. The EC_{20} value determined by regression analysis of percent normal fish versus whole-body tissue selenium concentration for the family Centrarchidae (most sensitive family or group of families) was 44.57 µg Se/g dw. Centrarchidae was the most sensitive family or group of families of those collected during the survey.

Chronic Value: The EC_{20} value determined by regression analysis of percent normal fish versus whole-body tissue selenium concentration for the family Centrarchidae was 44.57 µg Se/g dw.


Centrarchidae (Lemly 1993)
Normal (proportion)
1.0
0.8
0.6
0.4
0.2
0.0
1.0
2
3
4
5
6
7
8
10.0
2
3
4
5
6
7
100.0
Tissue Se [µg/g dw]

APPENDIX J

SELENIUM (µg/g dw WHOLE-BODY) IN FISH SAMPLES COLLECTED FROM 112 SITES AS PART OF U.S. FISH AND WILDLIFE'S NATIONAL BIOMONITORING PROGRAM, 1978-1981 (LOWE ET AL. 1985).

AND

SELENIUM (µg/g dw WHOLE-BODY) IN 322 AQUATIC LIFE TISSUE SAMPLES COLLECTED FROM 264 SITES AS PART OF USGS NATIONAL WATER QUALITY ASSESSMENT (NAWQA) PROGRAM (http://water.usgs.gov/nawqa/ as of May 11, 2004).

FCV Relative to Natural Background Levels of Selenium in Fish

As an essential element, selenium naturally occurs in all living things. Since selenium is found in all fish, two questions arise. 1) How close is the FCV of 7.91 µg/g dw to natural background levels in fish, and 2) how frequently do natural selenium tissue concentrations exceed the FCV. The latter situation would pose problems in the implementation of the FCV as an ambient water quality criterion.

As part of the National Contaminant Biomonitoring Program, the U.S. Fish and Wildlife Service collected fish from 112 sites distributed evenly across the U.S. during 1979 through 1981, and measured several contaminants including selenium (Lowe et al. 1985). Selenium, measured in 591 fish samples representing 60 different species, ranged from 0.3 to 10.5 µg/g dw and had an overall average and standard deviation of 1.9 ± 1.4 µg/g dw.

A separate data set of selenium levels in 231 macroinvertebrate samples, 90 fish samples, and one plant sample collected from 25 different states across the United States was generated by USGS's National Water Quality Assessment (NAWQA) program. NAWQA is intended to measure water quality in a sampling of smaller watersheds having known land use. Among these sites, whole body tissue concentrations ranged from 0.3 to 22.37 µg/g dw and had an overall average and standard deviation of 3.22 ± 2.29 µg/g dw. The distribution of both these data sets indicates that the FCV would not be exceeded by over 97 percent of aquatic tissue samples collected across the United States (Figure J-1). The FCV thus appears to be sufficiently greater than natural selenium levels that unavoidable exceedances of the criterion are unlikely.

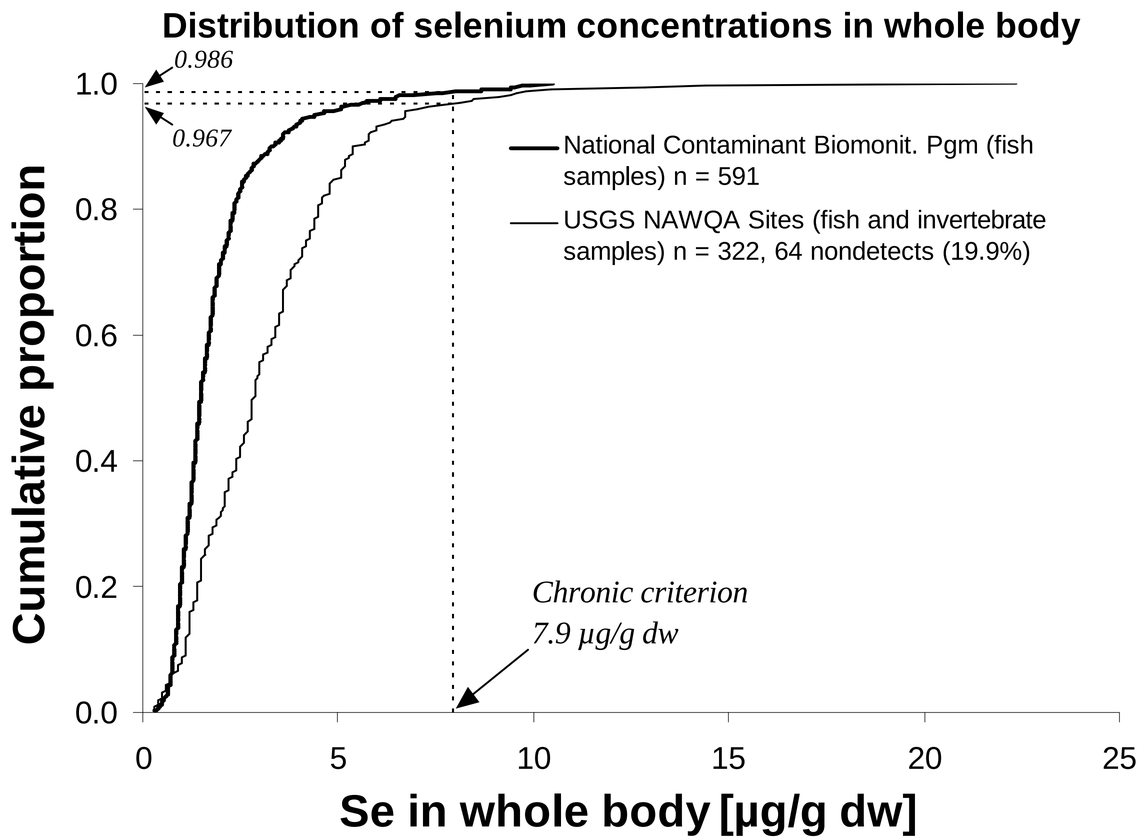


Figure J-1. Cumulative distribution of selenium concentrations in aquatic organisms (whole-body, µg/g dw) collected by the National Contaminant Biomonitoring Program (NCBP) and the U.S. Geological Service National Water-Quality Assessment (NAWQA) Program. NCBP and NAWQA data from Lowe et al. (1985) and query results from NAWQA's database on contaminant concentrations in animal tissues (http://water.usgs.gov/nawqa/), respectively.

Table J-1. Selenium (µg/g dw whole-body) in fish samples collected from 112 sites as part of U.S. Fish and Wildlife's National Biomonitoring Program, 1978-1981. From Lowe et al. 1985

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
		Station 1, Penobscot River at Old Town, MA		
78	Smallmouth bass	12.9	1.2	0.8562
78	White sucker	13.7	1.1	1.2227
78	White sucker	14.4	1.3	0.9292
80	Smallmouth bass	12.8	1.1	0.6513
80	White sucker	15.2	1.3	0.8261
80	White sucker	15.3	1.4	0.7634
		Station 2, Connecticut River at Windsor Locks, Conn.		
78	White catfish	16.6	2.3	0.4651
78	White catfish	16.5	2.3	0.6818
78	Yellow perch	8	0.3	0.9934
80	White catfish	14.5	0.9	0.6007
80	White catfish	13.3	0.9	0.9738
80	Yellow perch	9.5	0.4	0.9811
		Station 3, Hudson River at Poughkeepsie, NY		
78	Goldfish	11	1	0.9353
78	Goldfish	11.4	1.1	0.6545
78	Largemouth bass	11.1	0.8	1.0676
80	Goldfish	10.9	1	1.2333
80	Largemouth bass	14.8	2.2	1.0701
		Station 4, Delaware River at Trenton, NY- Yardley, Pa.		
79	White perch	7.3	0.2	4.6429
79	White sucker	12.8	0.8	1.1438
79	White sucker	14.3	1.2	0.8389
81	Largemouth bass	9.5	0.4	2.4206
81	White sucker	15	1.3	1.1864
81	White sucker	14.4	1.1	1.4423
		Station 5, Susquehanna River at Conowingo Dam, Md.		
79	Common carp	12.9	2	2.0690
79	Common carp	16.9	2.3	2.2381
79	White perch	7.6	0.3	5.5401
81	Common carp	14.4	1.6	2.5431
81	Common carp	14.1	1.7	1.5358
81	White perch	7.9	0.3	3.4951
		Station 6, Potomac River at Little Falls Md.- McLean Va		
79	Common carp	18.7	3.1	1.5248
79	Common carp	17	2.5	1.1628
79	Smallmouth bass	10	0.5	2.6587
81	Largemouth bass	11.5	8	1.8474
81	Redhorse	17.2	2	1.2963
81	Redhorse	17.5	2.1	1.3208
		Station 7, Roanoke river at Roanoke Rapids, N.C.		

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
78	White catfish	12.7	0.7	1.2134
80	Striped bass	14.5	1.4	1.3665
80	White catfish	11.7	0.6	1.0473
80	White catfish	10.1	0.4	1.0164
		Station 8, Cape Fear River at Elizabethtown, NC		
78	Spotted sucker	16.3	2	2.5177
78	Spotted sucker	16	2	2.5263
80	Flathead catfish	19	2	1.0656
80	Quillback	15	1.7	1.6719
80	Quillback	14.9	1.1	1.6558
		Station 9, Cooper River at Lake Moultrie, Monck;s Coner, S.C		
78	Channel catfish	16.3	1.3	1.6078
78	Channel catfish	14.6	1	1.4563
80	Channel catfish	14.5	1	1.4497
80	Channel catfish	13.6	0.6	1.4917
80	Striped bass	20.6	3.3	1.4894
		Station 10, Savannah River at Savannah, Ga		
78	Channel catfish	11	0.4	3.2444
78	White catfish	12.7	1	2.0248
80	White catfish	11.3	0.7	1.4592
80	White catfish	7.9	0.2	1.2319
80	Bowfin	21	3.6	2.2568
		Station 12, St. Lucie Canal at Indiantowm, Fla		
78	Largemouth bass			1.0954
78	White catfish			1.0580
78	White catfish			0.7931
80	Largemouth bass			1.1837
80	White catfish			1.3208
80	White catfish			0.9690
		Satation 13, Appalachicola River at J. Woodruff Dam, Fla.		
79	Largemouth bass			0.8803
79	Spotted sucker			1.8219
79	Spotted sucker			1.0980
81	Largemouth bass			0.9402
81	Spotted sucker			1.3060
81	Spotted sucker			1.5600
		Station 14, Tombigbee Tiver at McIntosh, Ala.		
79	Smallmouth buffalo			0.7325
79	Smallmouth buffalo			1.1513
81	Black crappie			1.2545
81	Blue catfish			0.8765
81	Blue catfish			0.7782
		Station 15, Mississippi Tiver at Luling, La.		

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
79	Common carp			1.6667
79	Common carp			1.7162
79	Largemouth bass			1.7200
81	Channel catfish			0.6599
81	Channel catfish			0.7561
81	Largemouth bass			1.8147
		Station 16, Rio Grande at Mission, Tex		
80	Gizzard shad			2.4638
80	Gizzard shad			2.4719
80	Largemouth bass			2.2800
81	Common carp			2.1858
81	Gizzard shad			2.6190
81	Gizzard shad			2.8125
		Station 17, Genessee River at Scottsville, NY		
80	Pumpkinseed			0.9901
80	Redhorse			0.7692
80	Redhorse			0.7328
81	Pumpkinseed			2.1186
81	Redhorse			1.2450
81	Redhorse			1.3853
		Station 18,, Lake Ontario at Prot Ontario, NY		
78	Rock bass			1.1355
79	Yellow perch			1.3306
79	Yellow perch			1.1719
81	Rock bass			1.4886
81	Yellow perch			1.7293
81	Yellow perch			1.3383
		Station 19, Lake Erie at Erie, Pa		
80	Redhorse			1.7625
80	Redhorse			1.7241
80	Yellow perch			2.4576
		Station 20, Lake Huron (Saginaw Bay) at Bay port, Mich.		
79	Common carp			1.8237
79	Common carp			1.9113
79	Yellow perch			1.9196
81	Common carp			2.3355
81	Common carp			2.5776
81	Yellow perch			2.1723
		Station 21, Lake Michigan at Sheboygan, Wis.		
79	Bloater			0.8060
79	Bloater			0.6897
79	Lake trout			1.1730
81	Bloater			0.7104

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
81	Bloater			0.9687
81	Lake trout			1.2828
	Station 22, Lake Superior at Bayfield, Wis.			
79	Lake trout			0.8911
79	Lake whitefish			1.3278
79	Lake whitefish			1.5058
81	Bloater			1.1304
81	Bloater			1.3419
81	Lake trout			1.4741
	Station 23, Kanawha River at Winfield, W.VA			
78	Channel catfish			0.9091
78	Channel catfish			0.8841
78	Sauger			1.4334
80	Channel catfish			0.9508
80	Channel catfish			1.2635
80	Sauger			2.3651
	Station 24, Ohio River at marietta, Ohio- Williamstown, W VA			
78	Channel catfish			1.1871
78	Sauger			1.4716
80	Common carp			2.2819
80	Common carp			1.7687
80	Sauger			2.2511
	Station 25, Cumberland River at Clarksville, Tenn.			
78	Common carp			1.3793
78	common carp			1.8077
78	White catfish			1.2203
80	Common carp			1.3514
80	Common carp			1.5909
80	Largemouth bass			1.7669
	Station 26, Illinois River at Beardstown, Ill.			
78	Black crappie			0.8638
78	Common carp			2.0438
78	Common carp			2.6766
80	Black crappie			1.5751
80	Common carp			1.8051
80	Common carp			2.1687
	Station 27, Mississippi River at Gutenburg, Iowa- Glen Haven, Wis.			
78	Common carp			1.7628
78	Common carp			1.3907
78	Largemouth bass			2.2742
80	Common carp			1.3231
80	Common carp			0.9064
80	Largemouth bass			1.1885

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
		Station 28, Arkansas River at Pine Bluff, Ark.		
79	Bluegill			0.8936
79	Common carp			1.2453
79	Common carp			1.0357
81	Common carp			1.7931
81	Common carp			1.3937
81	Largemouth bass			1.3011
		Station 29, Arkansas River at Keystone Reservoir, Okla.		
79	Common carp			1.3974
79	Common carp			1.6509
79	White bass			2.2167
81	Common carp			2.2394
81	Common carp			1.3410
81	White crappie			1.0738
		Station 30, White River at De Valls Bluff, Ark.		
79	Freshwater drum			0.8874
79	Freshwater drum			0.9091
79	Largemouth bass			0.8696
81	Common carp			2.2857
81	Common carp			1.7472
		Station 31, Missouri River at Nebraska City, Nebr.- Hamburg, Iowa		
79	Common carp			1.8774
79	Common carp			2.8163
79	Goldeye			1.2712
81	Common carp			3.0189
81	Common carp			3.2051
81	Goldeye			3.1803
		Station 32, Missouri River at Garrison Dam, N. Dak.		
79	Northern pike			1.4884
79	Redhorse			0.9600
81	Walleye			1.6041
81	White sucker			2.4883
81	White sucker			3.9252
		Station 33, Missouri River at Great Falls Mont.		
79	Brown trout			2.3432
79	White sucker			1.3333
79	White sucker			1.3158
81	Brown trout			2.1591
81	White sucker			1.9617
		Station 34, Red River of the Norh at Noyes, Minn. _ Pembina, N. Dak.		
78	Common carp			2.3166
78	Common carp			2.0629
78	Sauger			0.4682
80	Mooneye			3.3754

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
80	Sauger			0.9328
80	Sauger			0.8117
	Station 35, Green River at Vernal, Utah			
78	Common carp			3.7410
78	Common carp			3.9286
78	Smallmouth bass			3.6076
80	Common carp			3.2537
80	Common carp			2.7811
80	Smallmouth bass			3.1500
	Station 36, Colorado River at Imperial Reservoir, Ariz.- Calif.			
78	Common carp			6.5552
78	Common carp			8.0364
78	Largemouth bass			10.5204
80	Common carp			7.5210
80	Common carp			6.4783
80	Largemouth bass			8.6531
	Station 37, Truckee River at Fernley, Nev.			
80	Green sunfish			1.0794
80	Tahoe sucker			0.9211
80	Tahoe sucker			1.1401
81	Green sunfish			0.8835
	Station 38, Utah lake at Provo, Utah			
78	Common carp			2.9333
78	Common carp			3.1741
78	White bass			3.4799
80	Common carp			9.6863
80	Common carp			2.1633
80	White bass			3.5246
	Station 39, Sacramento River at Sacramento, Calif.			
79	Brown bullhead			0.7035
79	Largemouth bass			1.2644
79	largescale sucker			1.0811
81	largescale sucker			1.2454
81	Largemouth bass			1.4286
	Station 40, San Joaquin River at Los Banos, Calif.			
79	Black bullhead			3.3333
79	Black bullhead			3.3871
79	Green sunfish			6.0748
81	Sacramento blackfish			5.3425
81	Sacramento blackfish			5.7407
	Station 41, Snake River at Hagerman, Idaho			
78	Largescale sucker			1.2431
78	Largescale sucker			1.4126

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
78	Rainbow trout			2.3630
80	Largescale sucker			1.3913
80	Largescale sucker			1.5447
80	Rainbow trout			1.9495
	Station 42, Snake River at Lewiston, Idaho- Clarkston, Wash.			
78	Largescale sucker			0.9325
78	Largescale sucker			1.3636
78	Smallmouth bass			1.4765
80	Largescale sucker			0.8861
80	Largescale sucker			0.9746
80	White crappie			1.0870
	Station 43, Salmon River at Riggins, Idaho			
78	Bridgelip sucker			1.5719
78	Bridgelip sucker			0.8494
78	Northern squawfish			1.1930
80	Bridgelip sucker			0.9016
80	Bridgelip sucker			0.8475
80	Northern squawfish			2.9897
	Station 44, Yakima River at Granger, Wash.			
78	Common carp			2.3026
78	Common carp			1.4047
80	Black crappie			1.6716
80	Largescale sucker			1.7742
80	Largescale sucker			1.6508
	Station 45, Willamette River at Oregon City, Oreg			
78	Northern squawfish			0.5078
78	Chiselmouth			0.6615
78	Chiselmouth			0.4082
80	Largescale sucker			0.5479
80	Largescale sucker			0.6907
80	Northern squawfish			1.4286
	Station 46, Columbia River at Cascade Locks, Wash. -Oreg.			
78	Largescale sucker			1.2684
78	Largescale sucker			1.3712
78	Northern squawfish			1.7818
80	Largescale sucker			0.9236
80	Largescale sucker			0.6765
80	Northern squawfish			0.7025
	Station 47, Klamath River at br k, Calif.			
79	Klamath largescale sucker			0.3409
79	Klamath largescale sucker			0.3774
79	Yellow perch			0.6693
81	Klamath largescale sucker			1.0121

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
81	Yellow perch			0.9016
	Station 48, Rogue River at G)Id, y Da Oreg.			
79	Black crappie			0.3836
79	Redside shine			0.4887
81	Black crappie			0.3158
81	Brown bullhead			0.7805
81	Brown bullhead			0.7692
	Station 49, (,hena River at rks, aska			
79	Burbot			2.3005
79	Longnose sucker			1.2903
81	Longnose sucker			1.7757
81	Longnose sucker			1.8519
81	Northern pike			1.8026
	Station 50, Kenai River at SDidatna, laska			
78	Rainbow trout			2.0391
78	Round whitefish			2.9538
78	Dolly Varden			1.6992
80	Rainbow trout			1.8910
80	Round whitefish			1.8954
80	Dolly Varden			1.6910
	Station 51, Kennebec Rive at iiic y, Maine			
78	White sucker			1.1060
78	White sucker			0.9692
78	Yellow perch			1.2549
80	White sucker			1.0046
80	White sucker			0.9459
80	Yellow perch			0.7011
	Station 52 Lake Champlain Burlic gton, Vt.			
78	Northern pike			0.7451
78	White sucker			0.8400
78	White sucker			0.8676
80	Northern pike			1.1163
	Station 53, Menimack River t Low@ll, Mass.			
78	Largemouth bass			0.8070
78	White sucker			1.0357
78	White sucker			1.0676
80	Smallmouth bass			0.7343
80	White sucker			0.8230
80	White sucker			1.2389
	Station 54, Raritan River at Highland Park, N.J.			
78	Largemouth bass			1.8060
78	White sucker			1.9454

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
78	White sucker			1.8301
80	White sucker			1.5126
80	White sucker			2.3348
80	Redfin pickerel			1.6450
		Station 55, James River at Richmond, Va.		
79	Redhorse			1.2877
79	Redhorse			1.4194
79	Smallnouth bass			1.8657
81	Redhorse			1.9243
81	Redhorse			1.0658
81	Smallnouth bass			1.0359
		Station 56, Pee Dee River at Johnsonville, S.C.		
80	Gizzard shad			1.1170
80	Gizzard shad			1.0000
80	Largemouth bass			1.5235
		Station 57, Altamaha River at Doctortown, Ga.		
78	Black crappie			1.2857
78	Carpsucker			1.2342
80	Largemouth bass			1.7094
80	Spotted sucker			2.0408
80	Spotted sucker			1.5574
		Station 59, Alabama Rive'r at Chrysler, Ala.		
79	Smallmouth buffalo			1.0035
79	Smallmouth buffalo			1.0175
79	Bowfin			1.2203
81	Largemouth bass			1.1538
81	Blue catfish			0.6716
81	Blue catfish			0.7326
		Station 60, Brazos River a@ Richmond, Tex.		
79	Longnose gar			1.2681
79	Smallmouth buffalo			1.0320
79	Smallmouth buffalo			1.3693
		Station 61, Colorado River at Wharton, Tex.		
79	Channel catfish			0.9662
79	Freshwater drum			1.7844
79	Freshwater drum			1.4943
		Station 63, Rio Grande at Elephant Butte, N. Mex.		
78	Common carp			2.1514
78	Common carp			1.9028
78	Largemouth bass			1.9310
80	Common carp			1.7597
80	Common carp			1.5830

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
80	Largemouth bass			1.5709
		Station 64, Rio Grande at Alamosa, Colo.		
78	White sucker			0.7442
78	White sucker			0.9231
80	Brown trout			1.2775
80	White sucker			0.6911
80	White sucker			0.8036
		Station 65, Pecos River at Red Bltiff Lake, Tex.		
78	Gizzard shad			4.2715
78	White bass			9.5016
80	Gizzard shad			3.8559
80	Gizzard shad			5.0673
80	White bass			6.0681
		Station 66, St. Lawrence River at Massena, N.Y.		
79	Smallmouth bass			1.1765
79	White sucker			1.0280
79	White sucker			1.4414
81	Northern pike			1.3592
		Station 67, Allegheny River at Natrona, Pa.		
78	Redhorse			2.0155
78	Redhorse			1.4232
78	Smallmouth bass			2.2794
79	Largemouth bass			1.3693
79	Redhorse			1.9005
79	Redhorse			1.5789
80	Redhorse			2.7511
80	Redhorse			2.8139
80	Smallmouth bass			2.2656
		Station 68, Wabash River at New Harmony, -Crossville, III		
78	Common carp			2.0505
78	Common carp			2.2302
78	Largemouth bass			2.3413
80	Common carp			1.3043
80	Common carp			1.4873
80	Largemouth bass			1.5175
		Station 69, Ohio River at Cincinnati, Ohio		
78	Common carp			2.5890
78	Common carp			4.0333
78	Sauger			1.5031
80	Common carp			2.1071
80	Common carp			2.6070
80	Sauger			1.5113

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
		Station 70, Ohio River at Metropolis Ill.-Paducah, Ky.		
78	Common carp			2.2222
78	Common carp			1.4067
78	Largemouth bass			1.3514
80	Common carp			2.2118
80	Common carp			2.0599
80	Largemouth bass			1.7770
		Station 71, Tennessee iver at Savannah, Tenn.		
78	White bass			1.4610
79	Common carp			2.3790
79	Carpsucker			1.3333
80	Common carp			2.1973
80	Common carp			1.8103
80	Largemouth bass			1.9178
		Station 72, Wisconsin River at Woodman, Wis.		
80	Common carp			1.4107
80	Common carp			1.1688
80	Largemouth bass			1.1538
		Station 73, Des Moines River at Keosauqua, Iowa		
78	Common carp			3.5986
78	Common carp			4.0956
78	Sauger			2.4706
80	Common carp			3.8462
80	Common carp			2.3221
80	Channel catfish			1.7883
		Station 74, Mississippi River at Little Falls, Minn.		
78	White sucker			1.4340
78	Yellow perch			1.5825
80	rock bass			1.6207
80	Yellow bullhead			2.0155
80	Yellow bullhead			1.9149
		Station 75, Mississippi River at Cape Girardeau, Mo.-Ill		
78	Common carp			2.3511
78	Common carp			2.1019
78	White crappie			1.2360
80	Common carp			1.4449
80	Common carp			1.8077
80	White bass			2.8839
		Station 76, Mississippi River		
79	Bluegill			1.8000
79	Smallmouth buffalo			0.6818
79	Smallmouth buffalo			0.6140
81	Smallmouth buffalo			1.0979
81	Smallmouth buffalo			0.9884

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
81	White crappie			0.9343
		Station 78, Verdigris River at Oologah Okla.		
79	Common carp			1.0268
79	Common carp			1.4218
79	White bass			1.9907
81	Bluegill			1.7063
81	Common carp			2.1223
81	Common carp			2.1456
		Station 79, Canadian River at Eufaula, Okl.		
79	Common carp			2.4324
79	Common carp			1.4113
79	Largemouth bass			1.6318
81	Common carp			1.8382
81	Common carp			1.9403
81	Largemouth bass			2.3789
		Station 80, Yazoo River at Redwood, Miss		
79	Common carp			1.1620
79	Common carp			2.7356
81	Smallmouth buffalo			1.1875
81	Smallmouth buffalo			1.3559
81	White crappie			1.4444
		Station 81, Red River at Alexandria.		
79	Smallmouth buffalo			0.8929
79	Smallmouth buffalo			0.9667
79	White bass			1.3043
81	Freshwater drum			1.4103
81	Freshwater drum			1.2500
81	Spotted gar			0.7353
		Station 82, Red River at Lake Texoma, Okla.-Tex.		
79	Black crappie			1.2955
79	River carpsucker			1.3366
79	River carpsucker			1.7617
81	Common carp			1.8280
81	Common carp			2.4627
81	Largemouth bass			2.3043
		Station 83, Missoun River at Hermann, Mo.		
79	River carpsucker			0.9121
79	River carpsucker			1.1350
79	Smallmouth buffalo			1.4706
		Station 84, Bighorn River at Hardin, Mont.		
79	Common carp			5.6522
79	Goldeye			9.4118
79	White sucker			6.9466

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
81	Brown trout			5.0896
81	Longnose sucker			3.0717
	Station 85, Yellowstone River at Sidney,Mont.			
79	Common carp			1.4773
79	Common carp			1.9277
79	Sauger			1.7257
81	Redhorse			1.8919
81	Redhorse			2.4832
81	Sauger			1.6832
	Station 86, James River at Olivet, S. Dak vet, S. ak.			
79	Carpsucker			1.7188
79	Carpsucker			1.9184
79	Goldeye			1.7302
81	Carpsucker			1.0154
81	Carpsucker			1.2805
81	Goldeye			2.5185
	Station 87, North Platte River at Lak McConaughy, Nebr.			
79	Common carp			3.7288
79	Common carp			4.8918
79	Walleye			1.4907
81	Common carp			3.0488
81	Common carp			2.6601
81	Walleye			2.0077
79	Black crappie			2.7881
79	Common carp			4.3902
79	Common carp			4.3590
	Station 88, South Platte River at Brule, Nebr.			
81	White sucker			4.6538
81	Orangespotted sunfish			8.6786
	Station 89, Platte River at Lduisville Nebr.			
79	Carpsucker			2.2549
79	Carpsucker			1.6514
79	Goldeye			3.2335
81	Carpsucker			2.5207
81	Carpsucker			2.8270
81	Goldeye			4.0972
	Station 90, Kansas River at onner prings, Kans.			
79	Common carp			2.4615
79	River carpsucker			1.0676
81	Common carp			1.5858
81	Channel catfish			2.1635
81	River carpsucker			0.9859
	Station 91 Colorado River at Lake Havasu, Ariz.-Calif.			

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
78	Common carp			7.6490
78	Largemouth bass			5.1449
80	Common carp			3.6494
80	Common carp			5.6944
80	Largemouth bass			2.7666
	Station 92, Colorado River at Lake Mead Ariz.-Nev.			
79	Channel catfish			4.6441
79	Channel catfish			3.0169
79	Striped bass			0.8182
81	Common carp			3.3735
81	Channel catfish			3.2707
81	Striped bass			3.7109
	Station 93, Colorado v" t Lake 11, Ariz.			
78	Common carp			9.4218
78	Largemouth bass			9.8990
80	Common carp			4.3922
80	Common carp			3.9574
80	Largemouth bass			2.3759
	Station 94, Gfla River at Sa "IIDI servoir, Ariz.			
78	Common carp			1.9231
78	Common carp			1.5918
78	Largemouth bass			1.7466
80	Common carp			1.9588
80	Common carp			1.4079
80	Largemouth bass			1.1524
	Station 96, Snake River at I H @b, 'D.@'oWash			
78	Largescale sucker			1.0000
78	Largescale sucker			1.2625
78	Northern squawfish			0.8970
80	Largescale sucker			0.8765
80	Largescale sucker			0.8456
80	Northern squawfish			1.7316
	Station 97, Columbia River Pa,,O, sh.			
78	Yellow perch			3.8667
78	Chiselmouth			1.6242
78	Chiselmouth			1.2375
80	Common carp			4.0244
80	Common carp			2.6923
80	Yellow perch			3.5662
	Station 98, Columbia i,er G @,n 'C,uloee, Wash.			
78	Largescale sucker			0.8300
78	Largescale sucker			0.9266
78	Yellow perch			1.1847
80	Largescale sucker			0.7692

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
80	Largescale sucker			0.7519
80	Walleye			0.8108
		tation 99, Waikele Stea,	Waipah Hawaii	
79	Cuban limia			4.0755
		Station 100, Manoa Stream at Honol	Hawai	
79	Cuban limia			3.5577
79	Mazambique tilapia			1.6502
		Station 101, Androscoggin iver at	wiston, Main	
78	White sucker			0.9426
78	White sucker			0.7059
78	Yellow perch			0.7042
80	White sucker			0.6299
80	White sucker			0.5691
80	Yellow perch			0.8961
		Station 102, Laice Superior at@Keewe@naw Point, Mich.		
79	Bloater			1.2798
79	Bloater			0.9385
79	Lake trout			0.7339
81	Bloater			1.3354
81	Bloater			1.6961
81	Lake trout			1.4286
		Station 103, Lake Superior at Whitefish Point, Mich.		
79	Lake trout			0.7427
79	Lake whitefish			1.1379
79	Lake whitefish			1.8051
81	Lake trout			1.0617
81	Lake whitefish			1.4947
		104, Lake Michigan at Beavei,lsland,Mich.		
79	Bloater			0.8537
79	Bloater			0.4963
79	Lake trout			1.3483
		Station 105. Lake Michigan at Saugat@ck, Mich		
79	Bloater			0.4948
79	Bloater			0.6651
79	Lake trout			0.8310
81	Bloater			0.8696
81	Bloater			0.8939
81	Lake trout			1.1480
		Station 106, Lake Huron at Alpena Mich.		
79	White sucker			1.6596
79	White sucker			1.3793
79	Yellow perch			2.5556

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
81	Lake trout			1.2808
81	White sucker			2.3293
81	White sucker			2.2403
	Station 107, Lake St. Clair at Mount Clements. Mich.			
79	Common carp			1.2030
79	Common carp			1.6418
79	Walleye			1.7731
81	Common carp			1.8182
81	Common carp			2.0861
81	Walleye			1.9101
	Station 108, Lake Erie at Port Clinton. Ohio			
79	Common carp			1.4696
79	Common carp			1.4483
79	Walleye			0.6329
81	Common carp			2.1951
81	Common carp			1.6992
81	Walleye			1.0811
	Station 109, Lake Ontario at Roosevelt Beach, N.Y.			
79	Brown trout			1.1184
79	Rock bass			1.7626
79	Rock bass			1.4179
81	Lake trout			1.1310
81	Rock bass			1.6988
81	Rock bass			2.0949
	Station I I 1. Mississippi River at Lake City, Minn.-Pepin. Wis.			
78	White sucker			1.6867
78	White sucker			1.5203
80	Walleye			1.2162
80	White sucker			1.4231
80	White sucker			1.1020
	Station 112, Mississippi River at Dubuque, Iowa			
78	Common carp	12.9	1.1	1.8868
78	Common carp	14.4	1.5	1.4462
78	Largemouth bass	11.2	1.1	1.5901
80	Black crappic	10.2	0.7	1.6000
80	Common carp	17	2.6	2.2018
80	Common carp	17.8	3	1.4789
	Station 113, San Antonio River at McFadden, Tex.			
79	Longnose gar	28.5	2.3	0.7767
	Station 114, Bear River at Brigham City, Utah			
78	Common carp	11.7	0.8	1.5625
78	Common carp	10.2	0.6	0.9957
78	Channel catfish	17.9	2.3	1.3109

Year	Species	Mean total length, cm	Mean total weight, Kg	Se, ug/g dry wt.
80	Common carp	17	2.3	1.6667
80	Common carp	12	0.9	1.4583
80	Channel catfish	22.7	4.7	1.2551
		Station 115, Colorado River at Yuma, Ariz.- Winterhaven, Calif.		
78	Common carp	16	2.7	6.4815
78	Striped mullet	20.3	3.4	3.5958
		Station 116, Souris River at Upham, N. Dak.		
78	White sucker	16.5	2.3	1.0526
80	Northem pike	19.6	1.9	0.9709
80	White sucker	15.3	1.7	1.1161
80	White sucker	13.8	1.3	1.0331
		Station 117, Flathead River at Creston, Mont.		
78	Northem squawfish	19.1	2.7	0.7925
80	Largescale sucker	15.4	1.3	0.7589
80	Largescale sucker	15.5	1.3	0.9237
80	Northem squawfish	15.8	1.3	0.9091
			Average	1.8836
			Std	1.4373
			max	10.5204
			min	0.3158
			count	591

Table J-2. Selenium concentration (µg/g dw whole-body) in fish and invertebrate samples collected at sites of the USGS National Water Quality Assessment (NAWQA) Program, 1992-1997.

[Se]	Scientific Name	Common Name	Place Name
0.30	Odonata	-	GOOSE LAKE WMA
0.30	Hydropsyche	-	SF PALOUSE R. AT ARMSTRONG RD NR PULLMAN, WA
0.30	Hydropsyche	-	PALOUSE R. AT ENDICOTT-ST. JOHN RD NR COLFAX, WA
0.40	Odonata	-	JOHNSON WPA
0.40	Odonata	-	WOOD DUCK WMA
0.40	Corbicula	-	SALUDA RIVER NEAR COLUMBIA, SC
0.50	Pacifastacus leniusculus	signal crayfish	TRUCKEE R AT FARAD, CA
0.50	Odonata	-	DEPARTMENT OF ROADS - ONEILL
0.50	Odonata	-	TODD VALLEY - MEDUNA SITE
0.50	Micropterus salmoides	largemouth bass	TRINITY RV BL DALLAS, TX
0.60	Hydropsyche	-	ROCK CREEK BLW US HWY 30/93 AT TWIN FALLS ID
0.60	Pacifastacus leniusculus	signal crayfish	TRUCKEE R AT CLARK, NV
0.60	Hydropsyche	-	WOLF RIVER AT TURTLE LAKE ROAD AT POST LAKE, WI
0.60	Potamogeton pectinatus	sago pondweed	NORTH BRANCH MILWAUKEE RIVER NR RANDOM LAKE, WI
0.69	Tilapia melanotheron	blackchin tilapia	ALA WAI CANAL AT HONOLULU, HI
0.70	Hydropsyche	-	CRAB CREEK AT MORGAN LAKE ROAD NEAR OTHELLO, WA
0.70	Cottus sp.	freshwater sculpins	MILLER CREEK NEAR DES MOINES, WA
0.70	Cheumatopsyche	-	WOLF RIVER NEAR POST LAKE, WI
0.70	Hydropsyche	-	WOLF RIVER NEAR POST LAKE, WI
0.80	Hydropsyche	-	PESHEKEE RIVER NEAR MARTINS LANDING, MI
0.90	Catostomus clarki	desert sucker	PINTO CREEK NEAR MIAMI, AZ.
0.90	Odonata	-	SABATKA SALINE WETLAND
0.90	Corbicula	-	SYCAMORE CK AT SYCAMORE PK, FT WORTH, TX
0.90	Hydropsychidae	net-spinning caddisflies	WOLF RIVER AT HIGHWAY M NEAR LANGLADE, WI
1.00	Hydropsyche	-	SNAKE RIVER AT KING HILL ID
1.00	Cottus sp.	freshwater sculpins	BIG SOOS CREEK ABOVE HATCHERY NEAR AUBURN, WA
1.00	Orconectes	-	EAST RIVER AT MIDWAY ROAD NEAR DE PERE, WI
1.00	Hydropsyche	-	PENSAUKEE RIVER NEAR KRAKOW, WI
1.08	Poecilia sphenops	black molly	KANEOHE STR BLW KAMEHAMEHA HWY, OAHU, HI
1.10	Acroneuria	-	WEST BRANCH WHITEFISH RIVER NEAR DIFFIN, MI
1.10	Pacifastacus leniusculus	signal crayfish	EAST FORK CARSON RIVER NEAR GARDNERVILLE, NV
1.10	Pacifastacus leniusculus	signal crayfish	EAST FORK CARSON RIVER NEAR DRESSLERVILLE, NV
1.10	Cottus sp.	freshwater sculpins	SANDY RIVER NEAR TROUTDALE, OR
1.10	Cottus sp.	freshwater sculpins	GALES CREEK NEAR GLENWOOD, OR
1.10	Cottus sp.	freshwater sculpins	GALES CREEK NEAR GLENWOOD, OR
1.10	Hydropsyche	-	PALOUSE RIVER AT HOOPER, WA
1.10	Hydropsyche	-	SNAKE RIVER AB JACKSON LAKE AT FLAGG RANCH WY
1.10	Hydropsyche	-	SNAKE RIVER AB JACKSON LAKE AT FLAGG RANCH WY
1.15	Cheumatopsyche	-	DUCK CREEK AT SEMINARY ROAD NEAR ONEIDA, WI
1.20	Cyprinella lutrensis	red shiner	GRANITE CREEK AT PRESCOTT, AZ.
1.20	Orconectes causeyi	-	GRANITE CREEK AT PRESCOTT, AZ.
1.20	Catostomus occidentalis	Sacramento sucker	COTTONWOOD C NR COTTONWOOD CA
1.20	Xiphophorus helleri	green swordtail	WAIHEE STR NR KAHALUU, OAHU, HI
1.20	Hydropsyche	-	HENRYS FORK NR REXBURG ID
1.20	Hydropsyche	-	ROCK CREEK AB HWY 30/93 XING AT TWIN FALLS ID
1.20	Cottus sp.	freshwater sculpins	TUALATIN RIVER AT WEST LINN, OR

[Se]	Scientific Name	Common Name	Place Name
1.20	Cottus sp.	freshwater sculpins	DENNIS C BL BLACK BUTTE MINE, NR COTTAGE GROVE LK
1.20	Cottus sp.	freshwater sculpins	WEST BRANCH KELSEY CREEK AT BELLEVUE, WA
1.20	Cottus sp.	freshwater sculpins	BERTRAND CREEK NEAR LYNDEN, WA
1.20	Cheumatopsyche	-	TOMORROW RIVER NEAR NELSONVILLE, WI
1.20	Hydropsyche	-	SNAKE RIVER AB JACKSON LAKE AT FLAGG RANCH WY
1.30	Pacifastacus leniusculus	signal crayfish	TRUCKEE R AT FARAD, CA
1.30	Cottidae	sculpins	JOHNSON CREEK AT MILWAUKIE, OR
1.30	Micropterus salmoides	largemouth bass	WHITE ROCK LK IN DALLAS, TX
1.30	Cottus sp.	freshwater sculpins	DUWAMISH RIVER AT GOLF COURSE AT TUKWILA, WA
1.30	Hydropsyche	-	DUCK CREEK AT SEMINARY ROAD NEAR ONEIDA, WI
1.39	Cottus cognatus	slimy sculpin	NINILCHIK R AT NINILCHIK AK
1.40	Hydropsyche	-	PORTNEUF RIVER AT POCATELLO ID
1.40	Odonata	-	TRUST - WILD ROSE SLOUGH
1.40	Pacifastacus leniusculus	signal crayfish	TRUCKEE R AT HWY 447 AT NIXON, NV
1.40	Cottus sp.	freshwater sculpins	MARYS RIVER AT CORVALLIS, OR
1.40	Cottus sp.	freshwater sculpins	FIR CREEK NEAR BRIGHTWOOD, OR
1.40	Cottus sp.	freshwater sculpins	FANNO CREEK AT DURHAM, OR
1.40	Cottus sp.	freshwater sculpins	FANNO CREEK AT DURHAM, OR
1.40	Cheumatopsyche	-	DUCK CREEK AT SEMINARY ROAD NEAR ONEIDA, WI
1.40	Hydropsyche	-	NORTH BRANCH MILWAUKEE RIVER NR RANDOM LAKE, WI
1.50	Catostomus clarki	desert sucker	SAN PEDRO RIVER AT CHARLESTON, AZ.
1.50	Hydropsyche	-	ROCK CREEK AB DAYDREAM RANCH NR TWIN FALLS ID
1.50	Brachycentrus	-	ROCK CREEK AB HWY 30/93 XING AT TWIN FALLS ID
1.50	Odonata	-	TRUST - MORMON ISLAND CRANE MEADOW, EAST SLOUGH
1.50	Pacifastacus leniusculus	signal crayfish	CARSON RIVER AT DEER RUN ROAD NEAR CARSON CITY, NV
1.50	Pacifastacus leniusculus	signal crayfish	CARSON RIVER NEAR FORT CHURCHILL, NV
1.50	Cottidae	sculpins	MUDDY CREEK NEAR PEORIA, OR
1.50	Hydropsyche	-	PALOUSE RIVER NEAR COLFAX, WA
1.50	Cottus sp.	freshwater sculpins	THORNTON CREEK NEAR SEATTLE, WA
1.50	Hydropsyche	-	TOMORROW RIVER NEAR NELSONVILLE, WI
1.50	Hydropsyche	-	SALT RIVER AB RESERVOIR NR ETNA WY
1.50	Hydropsyche	-	SALT RIVER AB RESERVOIR NR ETNA WY
1.53	Cyprinus carpio	common carp	BEAR RIVER NEAR CORINNE, UT
1.60	Catostomus clarki	desert sucker	GILA RIVER AT KELVIN, AZ.
1.60	Hydropsyche	-	BARK RIVER NEAR BARK RIVER, MI
1.60	Cottidae	sculpins	FANNO CREEK AT DURHAM, OR
1.60	Elliptio	-	CEDAR CREEK BELOW MYERS CREEK NR HOPKINS, SC
1.60	Hydropsyche	-	PINE CREEK AT PINE CITY ROAD AT PINE CITY, WA
1.62	Corbicula	-	TRUCKEE R AT CLARK, NV
1.70	Hydropsyche	-	PORTNEUF RIVER AT TOPAZ ID
1.70	Hydropsyche	-	SNAKE RIVER AT KING HILL ID
1.70	Corbicula	-	TRENT RIVER NEAR TRENTON, NC
1.70	Elliptio	-	MCTIER CREEK (RD 209) NEAR MONETTA, SC
1.70	Corbicula	-	GILLS CREEK NEAR HOPKINS,SC
1.70	Hydropsyche	-	SHEBOYGAN RIVER AT DOTYVILLE, WI
1.79	Cottidae	sculpins	LITTLE ABIQUA CREEK NEAR SCOTTS MILLS, OR
1.80	Hydropsychidae	net-spinning caddisflies	TRUCKEE R AT FARAD, CA
1.80	Hydropsyche	-	TETON RIVER NR ST ANTHONY ID
1.80	Hydropsyche	-	SNAKE R NR MINIDOKA ID (AT HOWELLS FERRY)
1.90	Corbicula manilensis	asian clam	CHATTAHOOCHEE R AT SR 253 NEAR CHATTAHOOCHEE, FL
1.90	Hydropsyche	-	PALOUSE RIVER AT LAIRD PARK NR HARVARD, ID
1.90	Brachycentrus	-	ROCK CREEK AB HWY 30/93 XING AT TWIN FALLS ID
1.90	Hydropsyche	-	DUCK CREEK AT SEMINARY ROAD NEAR ONEIDA, WI
1.95	Poecilia sphenops	black molly	NUUANU STR ABV WAOLANI ST. AT HONOLULU, OAHU, HI
2.00	Hydropsyche	-	SPRING CREEK AT SHEEPSKIN RD NR FORT HALL ID
2.00	Acroneuria	-	PESHEKEE RIVER NEAR MARTINS LANDING, MI
2.00	Cheumatopsyche	-	DUCK CREEK AT SEMINARY ROAD NEAR ONEIDA, WI

[Se]	Scientific Name	Common Name	Place Name
2.03	Ameiurus natalis	yellow bullhead	SANTA ANA R A HAMNER RD NR NORCO CA
2.05	Richardsonius balteatus	redside shiner	BEAR RIVER ABOVE RESERVOIR, NEAR WOODRUFF, UT
2.10	Catostomus clarki	desert sucker	VERDE RIVER ABV W. CLEAR CREEK, NR CAMP VERDE, AZ
2.10	Hydropsyche	-	SNAKE R NR MINIDOKA ID (AT HOWELLS FERRY)
2.10	Hydropsyche	-	ROCK CK AT USFS FOOTBRIDGE, NR ROCK CREEK
2.10	Hydropsyche	-	ROCK CREEK AB HWY 30/93 XING AT TWIN FALLS ID
2.10	Pacifastacus leniusculus	signal crayfish	TRUCKEE R AT LOCKWOOD, NV
2.10	Hydropsyche	-	TUALATIN RIVER AT WEST LINN, OR
2.10	Hydropsyche	-	ESQUATZEL COULEE AT MESA, WA
2.10	Cottus sp.	freshwater sculpins	FISHTRAP CREEK AT FLYNN ROAD AT LYNDEN, WA
2.17	Corbicula fluminea	Asian clam	CONTENTNEA CREEK AT HOOKERTON, NC
2.18	Corbicula	-	TENNESSEE RIVER AT CHATTANOOGA, TN
2.20	Brachycentrus	-	BITCH CREEK NR LAMONT ID
2.20	Hydropsyche	-	SOUTH BRANCH PAINT RIVER NEAR ELMWOOD, MI
2.20	Cottus sp.	freshwater sculpins	LITTLE ABIQUA CREEK NEAR SCOTTS MILLS, OR
2.20	Ceratopsyche	-	EAST RIVER @ CTH PP IN BROWN COUNTY NR DE PERE, WI
2.20	Brachycentrus	-	SALT RIVERV NR FISH CK ABOVE SMOOT
2.30	Agosia chrysogaster	longfin dace	SANTA CRUZ RIVER AT TUBAC, AZ.
2.30	Catostomus clarki	desert sucker	WEST CLEAR CREEK NEAR CAMP VERDE, AZ.
2.30	Hydropsyche	-	PORTNEUF RIVER AT TOPAZ ID
2.37	Ameiurus natalis	yellow bullhead	SANTA ANA R A MWD CROSSING CA
2.40	Xiphophorus helleri	green swordtail	WAIKELE STR AT WAIPAHU, OAHU, HI
2.40	Hydropsyche	-	MALAD RIVER NR GOODING ID
2.40	Corbicula	-	CRABTREE CREEK AT US 1 AT RALEIGH, NC
2.40	Corbicula	-	BLACKWATER RIVER NEAR FRANKLIN, VA
2.40	Cottus sp.	freshwater sculpins	ROCK CREEK AT CEDAR FALLS ROAD NEAR LANDSBURG, WA
2.40	Cottus sp.	freshwater sculpins	JUANITA CREEK AT JUANITA, WA
2.50	Agosia chrysogaster	longfin dace	SALT RIVER NEAR ROOSEVELT, AZ.
2.50	Hydropsyche	-	SNAKE RIVER NR BLACKFOOT ID
2.50	Hydropsyche	-	SNAKE RIVER NR BLACKFOOT ID
2.50	Anaspidacea	-	EAST FORK CARSON RIVER NEAR GARDNERVILLE, NV
2.50	Elliptio	-	COOSAWHATCHIE RIVER NR EARLY BRANCH, SC
2.50	Corbicula	-	TAYLOR FLAT CREEK ABV BIRCH RD NR PASCO, WA
2.52	Xiphophorus helleri	green swordtail	MANOA STR AT KANEWAI FIELD, HONOLULU, OAHU, HI
2.60	Cottus sp.	freshwater sculpins	PALMER C AT DAYTON, OR
2.60	Elliptio	-	SHAWS CREEK NR TRENTON, SC ON CNTY RD 149
2.60	Corbicula	-	PIGEON RIVER AT NEWPORT, TN
2.60	Corbicula	-	RUSH CK AT WOODLAND PARK BLVD, ARLINGTON, TX
2.60	Cottus sp.	freshwater sculpins	NEWAUKUM CREEK NEAR BLACK DIAMOND, WA
2.64	Cyprinus carpio	common carp	SAN JACINTO R NR ELSINORE CA
2.70	Corbicula	-	EMORY RIVER AT OAKDALE, TN
2.70	Corbicula	-	GUADALUPE RV AT GONZALES, TX
2.70	Corbicula	-	NORTH MEHERRIN RIVER NEAR LUNENBURG, VA
2.70	Cottus sp.	freshwater sculpins	GREEN RIVER ABOVE TWIN CAMP CREEK NEAR LESTER, WA
2.70	Cottus sp.	freshwater sculpins	LEACH CREEK NEAR STEILACOOM, WA
2.70	Cottus sp.	freshwater sculpins	NORTH CREEK BELOW PENNY CREEK NEAR BOTHELL, WA
2.77	Gambusia affinis	western mosquitofish	MANOA STR AT KANEWAI FIELD, HONOLULU, OAHU, HI
2.79	Cottus sp.	freshwater sculpins	WEBER RIVER NEAR COALVILLE, UT
2.80	Corbicula manilensis	asian clam	MUCKALEE CREEK AT GA 195, NEAR LEESBURG, GA
2.80	Corbicula	-	TAR RIVER NEAR TAR RIVER, NC
2.80	Decapoda	crabs	PLATTE RIVER AT BRADY, NE (TOTFLO)
2.80	Corbicula	-	COPPER CREEK NEAR GATE CITY, VA
2.80	Brachycentrus	-	SECOND SOUTH BRANCH OCONTO RIVER NR MOUNTAIN, WI
2.80	Hydropsyche	-	TOMORROW RIVER NEAR NELSONVILLE, WI
2.80	Hydropsyche	-	NORTH BRANCH MILWAUKEE RIVER NR RANDOM LAKE, WI
2.80	Hydropsyche	-	SNAKE RIVER AB JACKSON LAKE AT FLAGG RANCH WY
2.81	Salvelinus fontinalis	brook trout	WOOD RIVER ABOVE MIDDLE FORK NEAR MEETEETSE, WY

[Se]	Scientific Name	Common Name	Place Name
2.85	Cottus cognatus	slimy sculpin	KENAI R AT JIMS LANDING NR COOPER LANDING AK
2.88	Salvelinus fontinalis	brook trout	CROW CREEK AT MOUTH, AT PAHASKA, WY
2.90	Corbicula manilensis	asian clam	APALACHICOLA RIVER AT CHATTAHOOCHEE FLA
2.90	Corbicula manilensis	asian clam	FLINT RIVER AT NEWTON, GA
2.90	Corbicula manilensis	asian clam	ICHAWAYNOCHAWAY CREEK BELOW NEWTON, GA
2.90	Corbicula manilensis	asian clam	PEACHTREE CREEK AT ATLANTA, GA
2.90	Corbicula manilensis	asian clam	FLINT RIVER AT LAKE BLACKSHEAR NEAR WARWICK, GA.
2.90	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER AT COLUMBUS, GA
2.90	Hydropsyche	-	SNAKE RIVER AT KING HILL ID
2.90	Corbicula	-	TRUCKEE R AT CLARK, NV
2.96	Cottus cognatus	slimy sculpin	CHESTER C AT ARCTIC BOULEVARD AT ANCHORAGE AK
2.96	Gambusia affinis	western mosquitofish	KANEOHE STR BLW KAMEHAMEHA HWY, OAHU, HI
3.00	Cottus cognatus	slimy sculpin	KENAI R BL RUSSIAN R NR COOPER LANDING AK
3.00	Hydropsyche	-	PORTNEUF RIVER AT TOPAZ ID
3.00	Brachycentrus	-	TETON RIVER AB SOUTH LEIGH CREEK NR DRIGGS ID
3.00	Corbicula fluminea	Asian clam	BIG BLUE RIVER AT SHELBYVILLE, IN
3.00	Corbicula	-	TAR RIVER AT TARBORO, NC
3.00	Corbicula	-	NORTH FLAT RIVER AT TIMBERLAKE, NC
3.00	Corbicula	-	GILLS CREEK AT COLUMBIA, SC
3.10	Perlidae	common stoneflies	BIG WOOD RIVER BLW BOULDER CK NR KETCHUM
3.10	Corbicula	-	NEUSE RIVER NEAR COX MILL, NC
3.10	Corbicula	-	SOUTH FORK CATAWBA RIVER AT MCADENVILLE, NC
3.10	Corbicula	-	INDIAN CREEK NEAR LABORATORY, NC
3.18	Corbicula manilensis	asian clam	SNAKE CREEK NEAR WHITESBURG, GA
3.20	Corbicula manilensis	asian clam	SPRING CREEK NEAR IRON CITY, GA.
3.20	Corbicula	-	ROANOKE RIVER AT ROANOKE RAPIDS, NC
3.20	Corbicula	-	NOTTOWAY RIVER NEAR SEBRELL, VA
3.30	Corbicula manilensis	asian clam	BULL CREEK AT US 27 AT COLUMBUS, GEORGIA
3.30	Corbicula	-	CONOCOCHEAGUE CREEK AT FAIRVIEW, MD
3.30	Decapoda	crabs	WOOD RIVER NEAR GRAND ISLAND NEBR
3.30	Corbicula	-	NOLICHUCKY RIVER NEAR LOWLAND
3.40	Corbicula fluminea	Asian clam	SUGAR CREEK AT CO RD 400 S AT NEW PALESTINE, IN
3.40	Ceratopsyche	-	WEST BRANCH WHITEFISH RIVER NEAR DIFFIN, MI
3.40	Cheumatopsyche	-	JOHNSON CREEK AT MILWAUKIE, OR
3.40	Corbicula	-	POWELL RIVER NEAR ARTHUR, TN
3.40	Hydropsyche	-	PARADISE CREEK AT PULLMAN, WA
3.40	Hydropsyche	-	SALT RIVER AB RESERVOIR NR ETNA WY
3.50	Corbicula manilensis	asian clam	FLINT R @ 10-MI STILL LANDING NR CHATTAHOOCHEE, FL
3.50	Corbicula manilensis	asian clam	PEACHTREE CREEK AT ATLANTA, GA
3.50	Corbicula	-	NEUSE RIVER AT KINSTON, NC
3.50	Corbicula fluminea	Asian clam	NEUSE RIVER AT KINSTON, NC
3.50	Corbicula	-	SANTEE R AT TREZESVANTS LANDING NR FT MOTTE, SC
3.50	Corbicula	-	NOLICHUCKY RIVER AT EMBREEVILLE, TN
3.50	Corbicula	-	SAN MARCOS RV ABV BLANCO RV BL SAN MARCOS, TX
3.60	Cyprinella lutrensis	red shiner	SALT RIVER NEAR ROOSEVELT, AZ.
3.60	Agosia chrysogaster	longfin dace	AGUA FRIA RIVER NEAR ROCK SPRINGS, AZ.
3.60	Carpiodes carpio	river carpsucker	BUCKEYE CANAL NR HASSAYAMPA
3.60	Corbicula	-	48TH STREET DRAIN NR INTERSTATE 10
3.60	Corbicula manilensis	asian clam	APALACHICOLA RIVER NR BLOUNTSTOWN,FLORIDA
3.60	Corbicula manilensis	asian clam	CHATTAHOOCHEE R AT SR 369 NR FLOWERY BRANCH, GA.
3.60	Corbicula	-	SWIFT CREEK AT HILLIARDSTON, NC
3.60	Corbicula	-	CHICOD CR AT SR1760 NEAR SIMPSON, NC
3.60	Corbicula	-	LITTLE RIVER NEAR MARYVILLE, TN
3.60	Hydropsyche	-	CRAB CREEK AT ROCKY FORD ROAD NEAR RITZVILLE, WA
3.60	Cottus sp.	freshwater sculpins	ROCK CREEK NEAR MAPLE VALLEY, WA
3.60	Cottus sp.	freshwater sculpins	NOOKSACK RIVER AT BRENNAN, WA

[Se]	Scientific Name	Common Name	Place Name
3.66	Corbicula	-	CONGAREE RIVER AT COLUMBIA, SC
3.70	Corbicula manilensis	asian clam	KINCHAFOONEE CREEK NEAR DAWSON, GA
3.70	Hydropsyche	-	BLACKFOOT RIVER AB RESERVOIR NR HENRY ID
3.70	Corbicula fluminea	Asian clam	WHITE RIVER AT RAYMOND STREET AT INDIANAPOLIS, IN
3.70	Corbicula manilensis	asian clam	CURRENT RIVER AT VAN BUREN, MO
3.77	Corbicula	-	HOLSTON RIVER AT SURGOINSVILLE, TN
3.80	Corbicula manilensis	asian clam	APALACHICOLA RIVER NR SUMATRA,FLA.
3.80	Corbicula	-	SWIFT CREEK NEAR APEX, NC
3.80	Cottus sp.	freshwater sculpins	LUCKIAMUTE RIVER NEAR SUVER, OR
3.80	Corbicula	-	CATOCTIN CREEK AT TAYLORSTOWN, VA
3.85	Corbicula manilensis	asian clam	SOPE CREEK NEAR MARIETTA, GA
3.90	Corbicula manilensis	asian clam	NICKAJACK CR AT COOPER LAKE DR NR MABLETON, GA.
3.90	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER NEAR COLUMBIA, ALA.
4.00	Elliptio	-	GEORGES CREEK NEAR OLAR, SC ON SC 64
4.00	Corbicula	-	WATEREE RIVER NR. CAMDEN, SC
4.01	Cyprinus carpio	common carp	LEON CK AT IH 35 AT SAN ANTONIO, TX
4.10	Corbicula manilensis	asian clam	WILLEO CREEK AT ST RT 120 NEAR ROSWELL, GA.
4.10	Hydropsyche	-	MALAD RIVER NR GOODING ID
4.10	Corbicula	-	CARSON RIVER AT TARZYN ROAD NR FALLON, NV
4.10	Corbicula	-	FRENCH BROAD RIVER NEAR NEWPORT, TN
4.10	Corbicula	-	MIDDLE FORK HOLSTON RIVER AT SEVEN MILE FORD, VA
4.16	Corbicula	-	OBED RIVER NEAR LANCING, TN
4.20	Corbicula manilensis	asian clam	SEWELL MILL CR AT SEWELL MILL RD NEAR MARIETTA
4.20	Arctopsyche	-	BIG LOST RIVER AT HOWELL RANCH NR CHILLY ID
4.20	Corbicula	-	CONGAREE RIVER AT U.S. HWY 601 NR. FORT MOTTE, SC
4.20	Corbicula	-	GUADALUPE RV NR SPRING BRANCH, TX
4.30	Agosia chrysogaster	longfin dace	GILA RIVER AT KELVIN, AZ.
4.30	Corbicula manilensis	asian clam	SOPE CREEK NEAR MARIETTA, GA
4.30	Corbicula manilensis	asian clam	AYCOCKS CREEK NEAR BOYKIN, GA.
4.30	Elliptio	-	COW CASTLE CREEK NEAR BOWMAN, SC
4.30	Corbicula	-	NORTH FORK HOLSTON RIVER NEAR CLOUD FORD, TN
4.40	Cottus cognatus	slimy sculpin	TALKEETNA R NR TALKEETNA AK
4.40	Corbicula manilensis	asian clam	COOLEEWAHEE CREEK NEAR NEWTON, GA.
4.40	Corbicula manilensis	asian clam	SOPE CREEK NEAR MARIETTA, GA
4.40	Corbicula manilensis	asian clam	FLINT RIVER NEAR CULLODEN, GA
4.40	Corbicula fluminea	Asian clam	CLIFTY CREEK AT HARTSVILLE, IN
4.40	Pacifastacus leniusculus	signal crayfish	CARSON RIVER NEAR FORT CHURCHILL, NV
4.47	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER NEAR WHITESBURG, GA
4.50	Agosia chrysogaster	longfin dace	SAN PEDRO RIVER AT CHARLESTON, AZ.
4.50	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER NEAR NORCROSS, GA
4.50	Arctopsyche	-	BIG LOST RIVER AT HOWELL RANCH NR CHILLY ID
4.50	Corbicula fluminea	Asian clam	LOST RIVER NEAR LEIPSIC, IN
4.50	Corbicula	-	CLINCH RIVER ABOVE TAZEWELL, TN
4.50	Corbicula	-	ESQUATZEL COULEE AT SAGEMOOR RD NEAR PASCO, WA
4.57	Corbicula	-	CHAMBERS CK NR RICE, TX
4.60	Corbicula manilensis	asian clam	FLAT SHOAL CREEK AT STOVALL RD NEAR STOVALL, GA
4.60	Corbicula	-	BIG LIMESTONE CREEK NEAR LIMESTONE, TN
4.60	Corbicula	-	SALADO CK AT LOOP 13 AT SAN ANTONIO, TX
4.64	Corbicula	-	CONGAREE RIVER AT COLUMBIA, SC
4.76	Catostomus commersoni	white sucker	SADDLE RIVER AT RIDGEWOOD NJ
4.80	Agosia chrysogaster	longfin dace	PINTO CREEK NEAR MIAMI, AZ.
4.80	Corbicula manilensis	asian clam	SNAKE CREEK NEAR WHITESBURG, GA
4.80	Corbicula	-	BEAVER CREEK BELOW LIBERTY HILL, SC
4.80	Cottus sp.	freshwater sculpins	NF SKOKOMISH R BL STAIRCASE RPDS NR HOODSPORT, WA
4.80	Cottus sp.	freshwater sculpins	NOOKSACK RIVER AT NORTH CEDARVILLE, WA
4.81	Corbicula	-	NORTH FORK HOLSTON RIVER NEAR HAYTER GAP, VA
4.86	Cottus cognatus	slimy sculpin	CHESTER C AT ARCTIC BOULEVARD AT ANCHORAGE AK
5.09	Corbicula	-	MENARD CK NR FUQUA, TX

[Se]	Scientific Name	Common Name	Place Name
5.10	Corbicula manilensis	asian clam	LIME CREEK NEAR COBB, GA
5.10	Corbicula fluminea	Asian clam	KESSINGER DITCH NEAR MONROE CITY, IN
5.10	Corbicula fluminea	Asian clam	SALT CREEK AT HOOSIER AVENUE AT OOLITIC, IN
5.10	Cottus sp.	freshwater sculpins	SKOKOMISH RIVER NEAR POTLATCH, WA
5.13	Cottus sp.	freshwater sculpins	BEAR RIVER BELOW SMITHS FORK, NEAR COKEVILLE, WY
5.19	Cottus cognatus	slimy sculpin	KAMISHAK R NR KAMISHAK AK
5.20	Cyprinella lutrensis	red shiner	AGUA FRIA RIVER NEAR ROCK SPRINGS, AZ.
5.20	Corbicula fluminea	Asian clam	SUGAR CREEK AT CO RD 400 S AT NEW PALESTINE, IN
5.20	Corbicula	-	SOUTH BRANCH POTOMAC RIVER NEAR SPRINGFIELD, WV
5.30	Corbicula fluminea	Asian clam	EAST FORK WHITE RIVER AT SHOALS, IN
5.30	Corbicula	-	EDISTO RIVER NEAR COTTAGEVILLE,SC
5.40	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER NEAR CORNELIA, GA
5.40	Corbicula manilensis	asian clam	WEST FORK LITTLE RIVER NEAR GAINESVILLE, GA.
5.40	Corbicula	-	TRUCKEE R AT LOCKWOOD, NV
5.40	Corbicula	-	BRUSHY CREEK NEAR PELHAM, SC
5.40	Corbicula	-	BIG CREEK ABOVE SALUDA, SC
5.70	Corbicula	-	AHOSKIE CR NEAR POORTOWN, NC
5.70	Corbicula	-	CLINCH RIVER AT SPEERS FERRY, VA
5.78	Hemichromis	jewelfishes	POAMOHO STREAM NR WAIALUA, OAHU, HI
5.79	Corbicula	-	KNOB CREEK AT AUSTIN SPRINGS
5.80	Corbicula manilensis	asian clam	FLINT RIVER NEAR LOVEJOY, GA
5.80	Corbicula	-	SABINAL RV NR SABINAL, TX
5.81	Cottus cognatus	slimy sculpin	MOOSE C NR PALMER AK
6.00	Corbicula fluminea	Asian clam	MUSCATATUCK RIVER NEAR DEPUTY, IN
6.00	Corbicula	-	LICK CREEK NEAR HOLLAND MILL, TN
6.00	Hydropsyche	-	CHAFFEE CREEK AT NESHKORO, WI
6.20	Corbicula	-	MEDINA RV AT LA COSTE, TX
6.30	Corbicula	-	INDIAN CREEK ABOVE NEWBERRY, SC
6.35	Cottus cognatus	slimy sculpin	SF CAMPBELL C NR ANCHORAGE AK
6.68	Cottus cognatus	slimy sculpin	COSTELLO C AB CAMP C NR COLORADO AK
6.70	Agosia chrysogaster	longfin dace	AGUA FRIA RIVER NEAR MAYER, AZ.
6.70	Agosia chrysogaster	longfin dace	AGUA FRIA RIVER AT BLOODY BASIN ROAD
6.70	Corbicula manilensis	asian clam	CHATTAHOOCHEE RIVER NEAR WHITESBURG, GA
6.70	Corbicula	-	BLANCO RV AT WIMBERLEY, TX
7.00	Corbicula	-	LONG CREEK ON SPENCER MTN RD NR SPENCER MTN, NC
7.30	Corbicula	-	GUEST RIVER AT COEBURN, VA
7.70	Corbicula	-	FRIO RV AT CONCAN, TX
8.10	Corbicula	-	VERDE R BLW TANGLE CREEK, ABV HORSESHOE DAM, AZ.
8.40	Corbicula	-	COMAL RV AT NEW BRAUNFELS, TX
8.47	Cottus cognatus	slimy sculpin	COSTELLO C NR COLORADO AK
9.10	Corbicula	-	NUECES RV BL UVALDE, TX
9.40	Cyprinella lutrensis	red shiner	VERDE R BLW TANGLE CREEK, ABV HORSESHOE DAM, AZ.
9.56	Cottus cognatus	slimy sculpin	CAMP C AT MOUTH NR COLORADO AK
9.83	Ictalurus punctatus	channel catfish	SABINAL RV NR SABINAL, TX
10.47	Cottus cognatus	slimy sculpin	COSTELLO C BL CAMP C NR COLORADO AK
12.83	Corbicula	-	GERONIMO CK AT HWY 90A NR SEGUIN, TX
14.40	Hydropsyche	-	GREEN CREEK NEAR PALMER, MI
22.37	Salmo trutta	brown trout	TONGUE RIVER NEAR DAYTON, WY