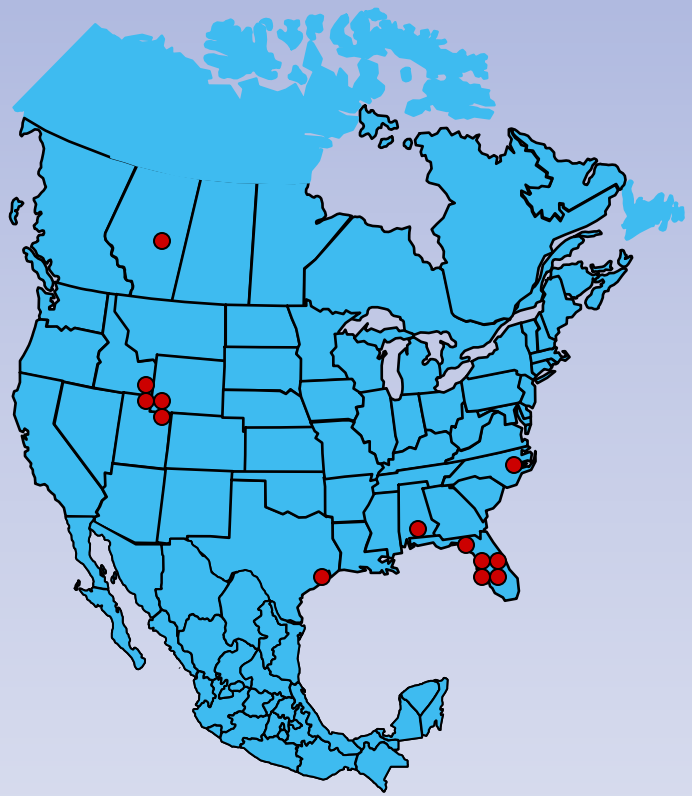
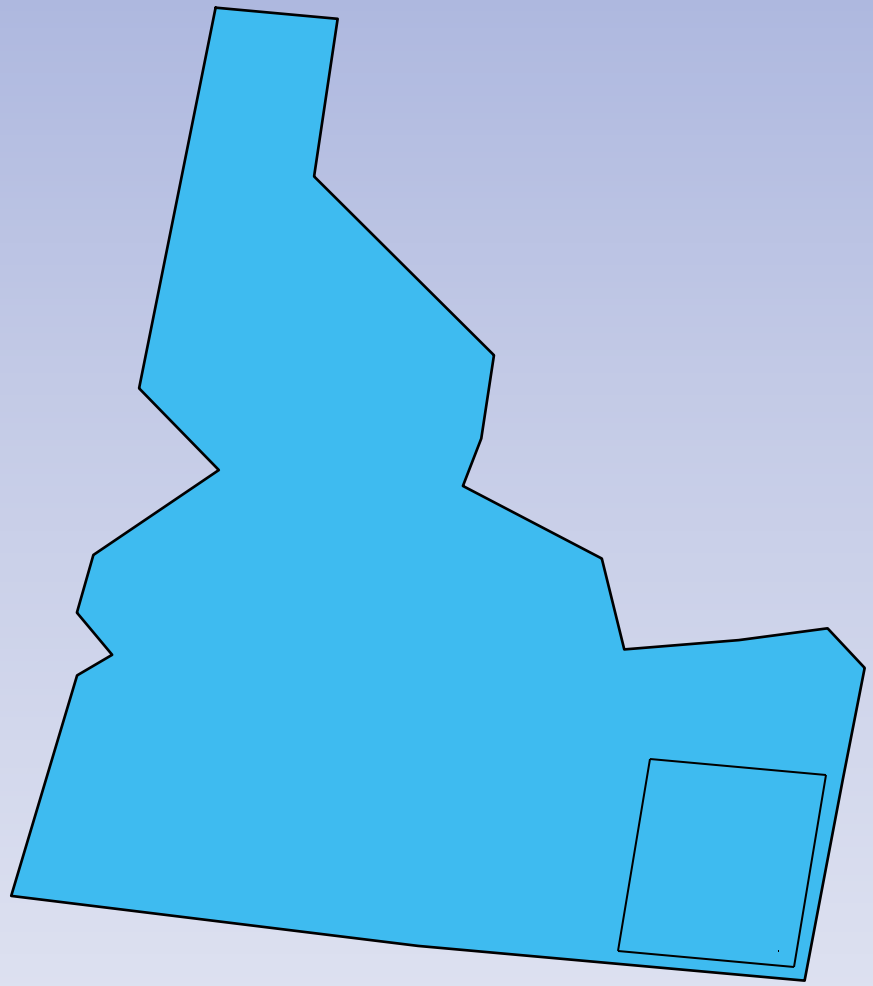
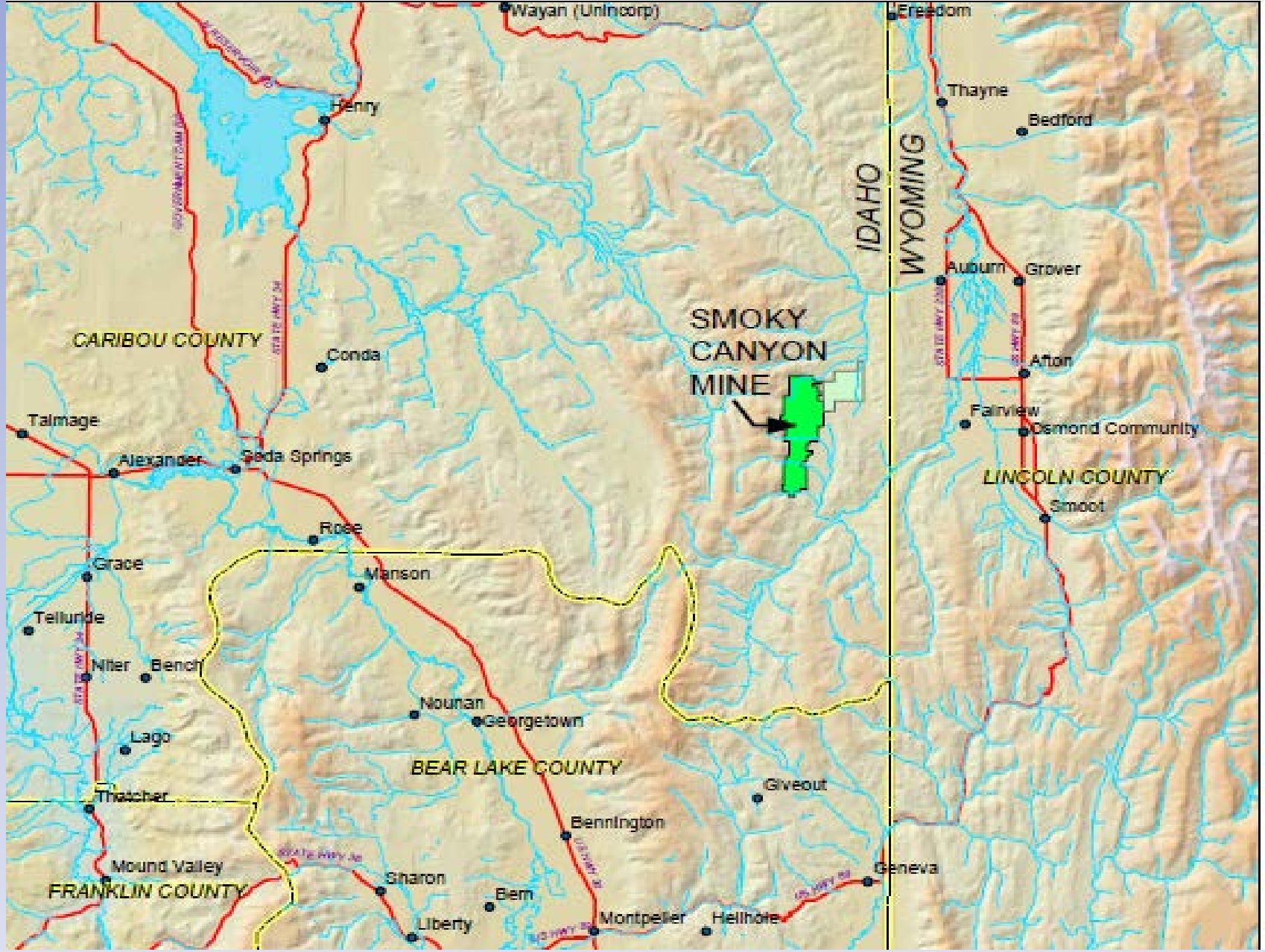
Proposal for a Site-Specific Selenium Criterion in Southeast Idaho

Smoky Canyon Mine
Caribou County, Idaho
June 2017

North America Phosphates







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Resident Fish

Key species:

- Brown trout
- Yellowstone cutthroat trout.

Technical Approach

- Field Monitoring Studies
  - Characterize exposure environment
  - Fish and invertebrate community condition
- Field/Laboratory Testing
  - Adult Reproductive Success
  - Early Life Stage (ELS) Study
- Literature Review
  - Range of species sensitivities
- Develop tissue based effects value

Cooperative Agency Involvement

- Simplot worked collaboratively with personnel from:
  - Idaho Department of Environmental Quality (IDEQ)
  - Idaho Department of Fish and Game (IDFG)
  - Environmental Protection Agency (USEPA)
  - Fish and Wildlife Service (USFWS – invited but did not participate)
  - Forest Service (USFS)
  - Wyoming Department of Environmental Quality (WDEQ)

- Frequent discussions, agency input, and review on approach, methods, and procedural issues

Basis for Site-Specific Standards

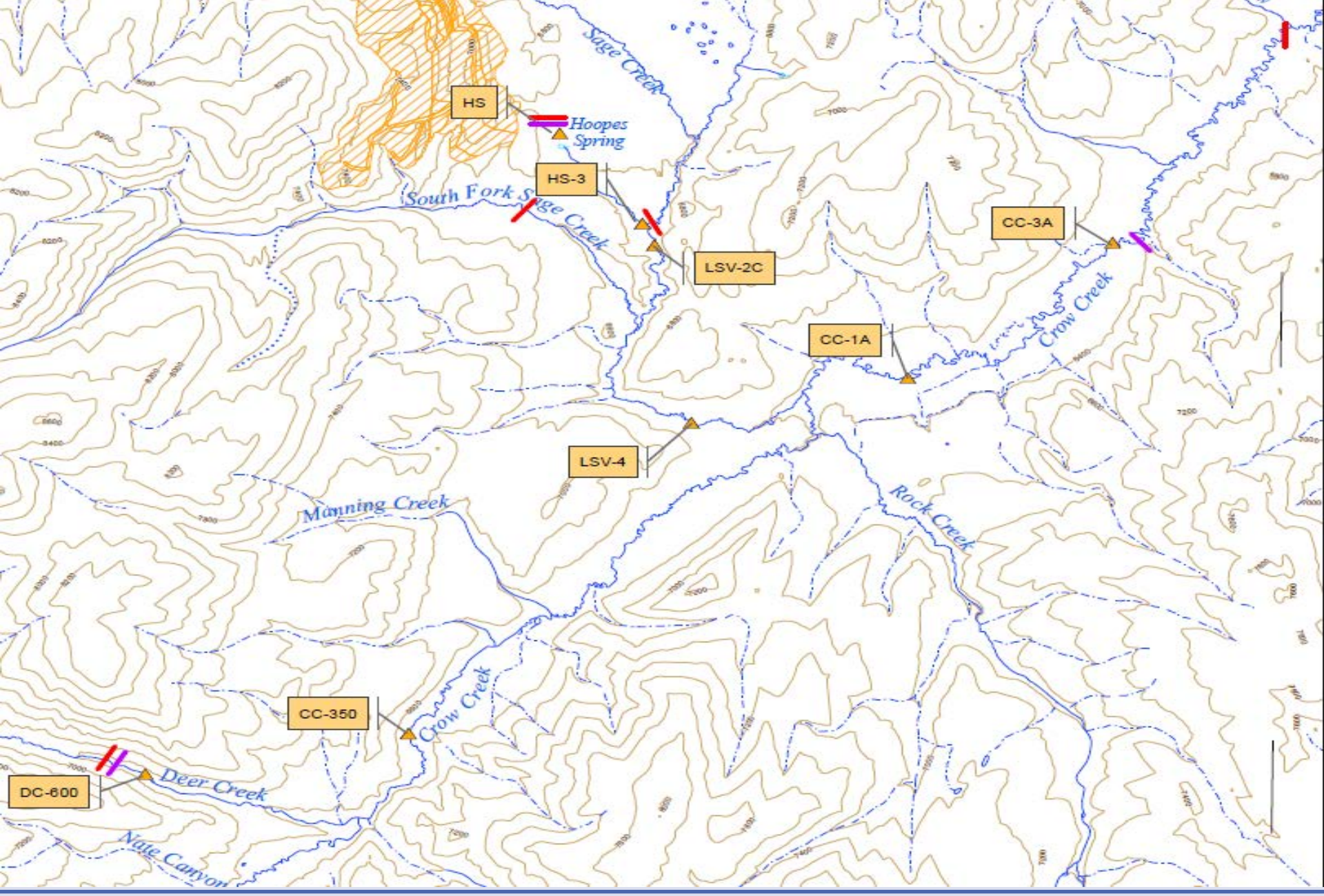
[IDAPA 58.01.02.275]

1. Resident species are more or less sensitive than those species used to develop a water quality criterion.
2. Biological availability and/or toxicity may be altered due to differences between the physicochemical characteristics of the water in a water body and the lab water used in developing water quality criterion.

Rules describe involvement of the Department in the work for scientific validity of the work.

Conduct Supporting Studies

- Laboratory Studies
  - Characterize effects using site species and exposures
- Compile and evaluate the current literature
  - Use literature as basis for developing the study and evaluating its results
- Conduct field studies
  - Characterize the exposure environment



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Wild Fish Collection

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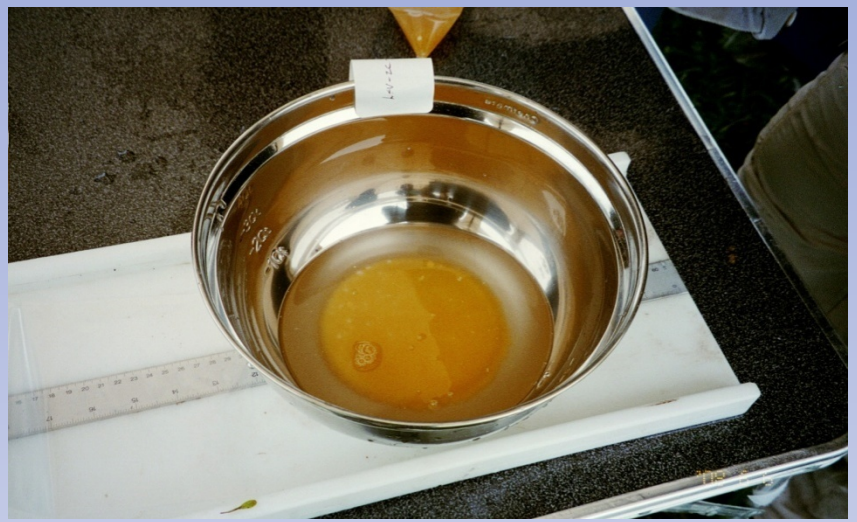
Collect Eggs



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Adult Reproduction Studies

Collect adult pre-spawn wild fish – collect gametes and raise eggs in the lab

Hatch eggs

Raise to swim up or other periods when active feeding begins

Measure Endpoints

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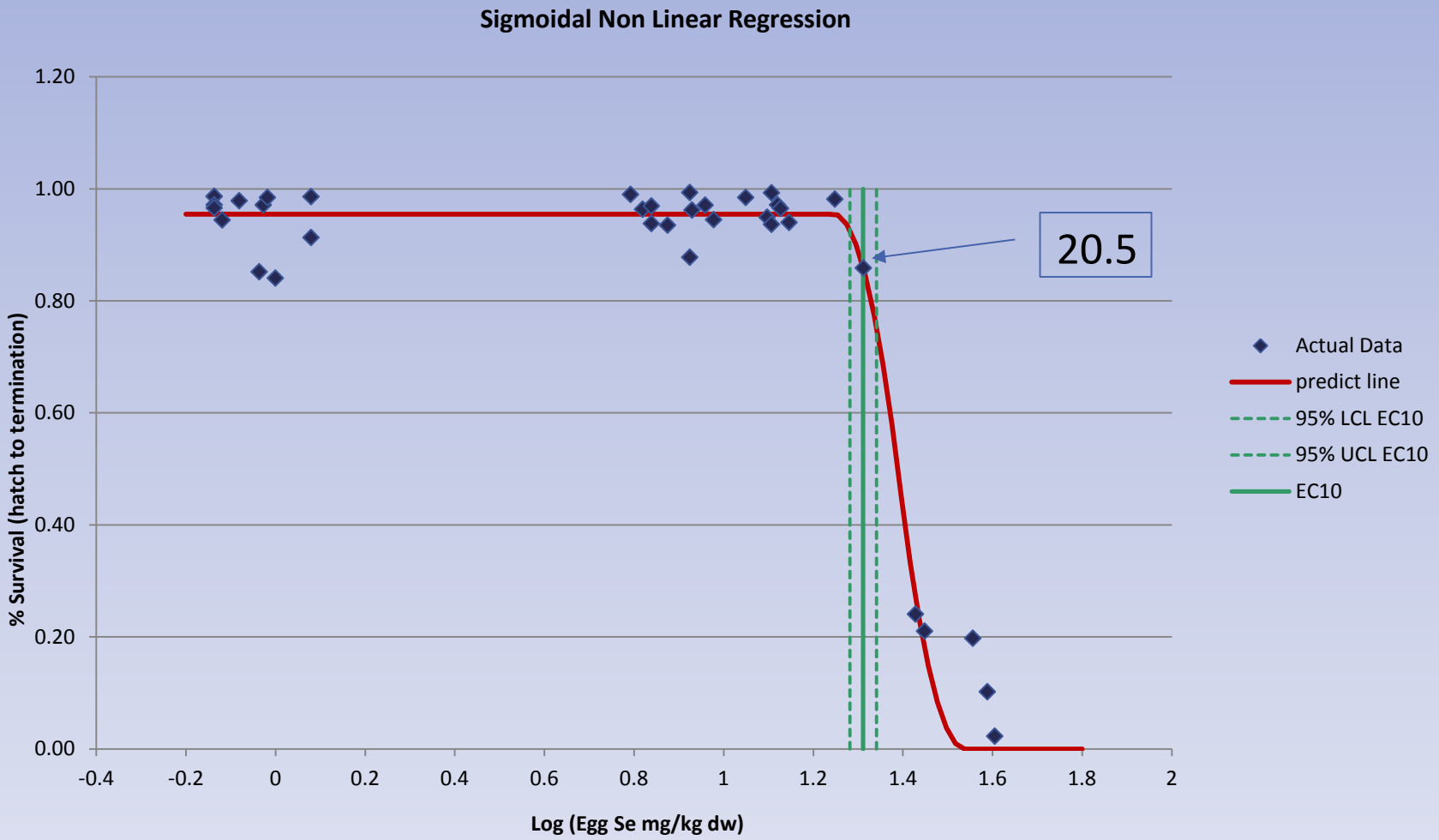
Sigmoidal Non Linear Regression of Brown Trout Egg Selenium Concentrations Versus Survival Percentage (Hatch to Test End)



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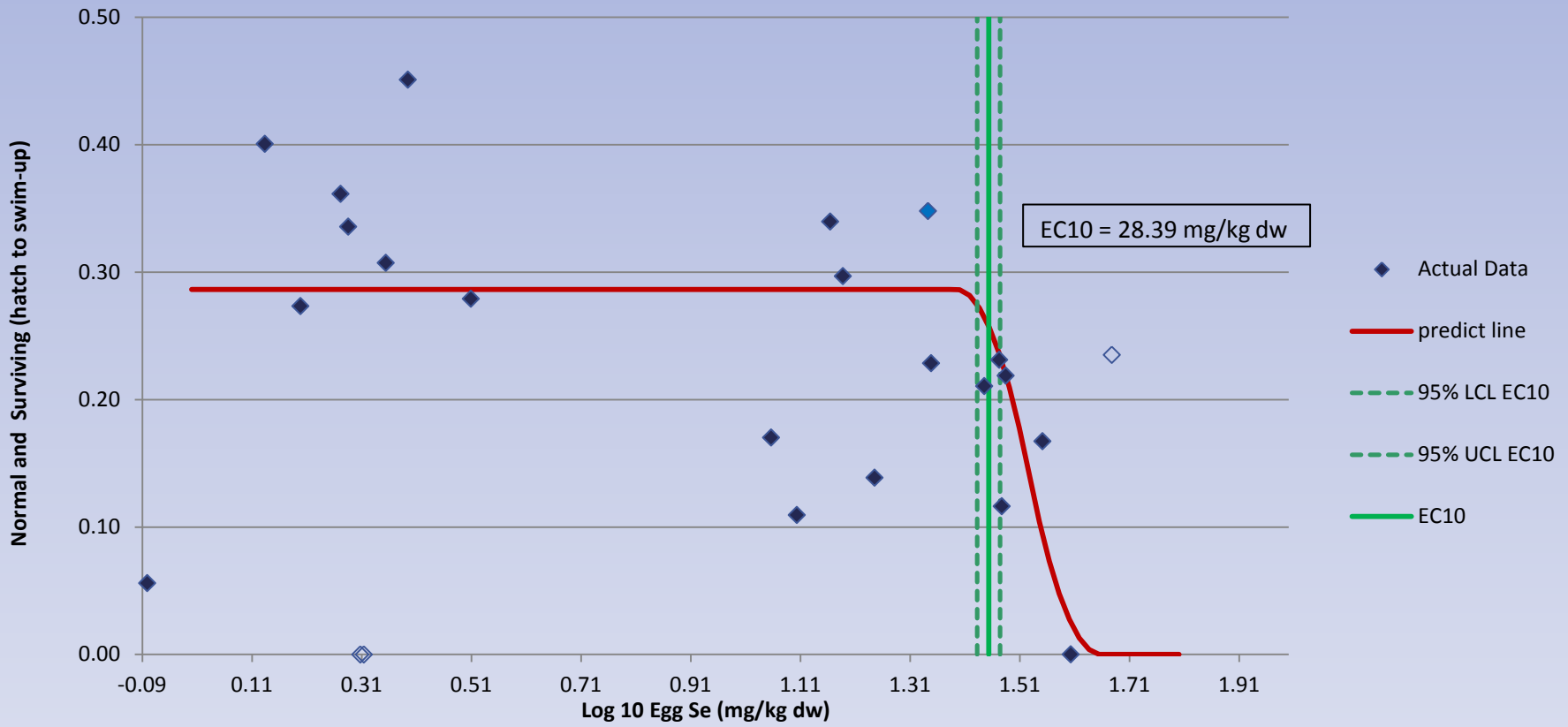
Relationship of YCT Egg Selenium Concentrations to Proportion of Normal and Surviving Fry



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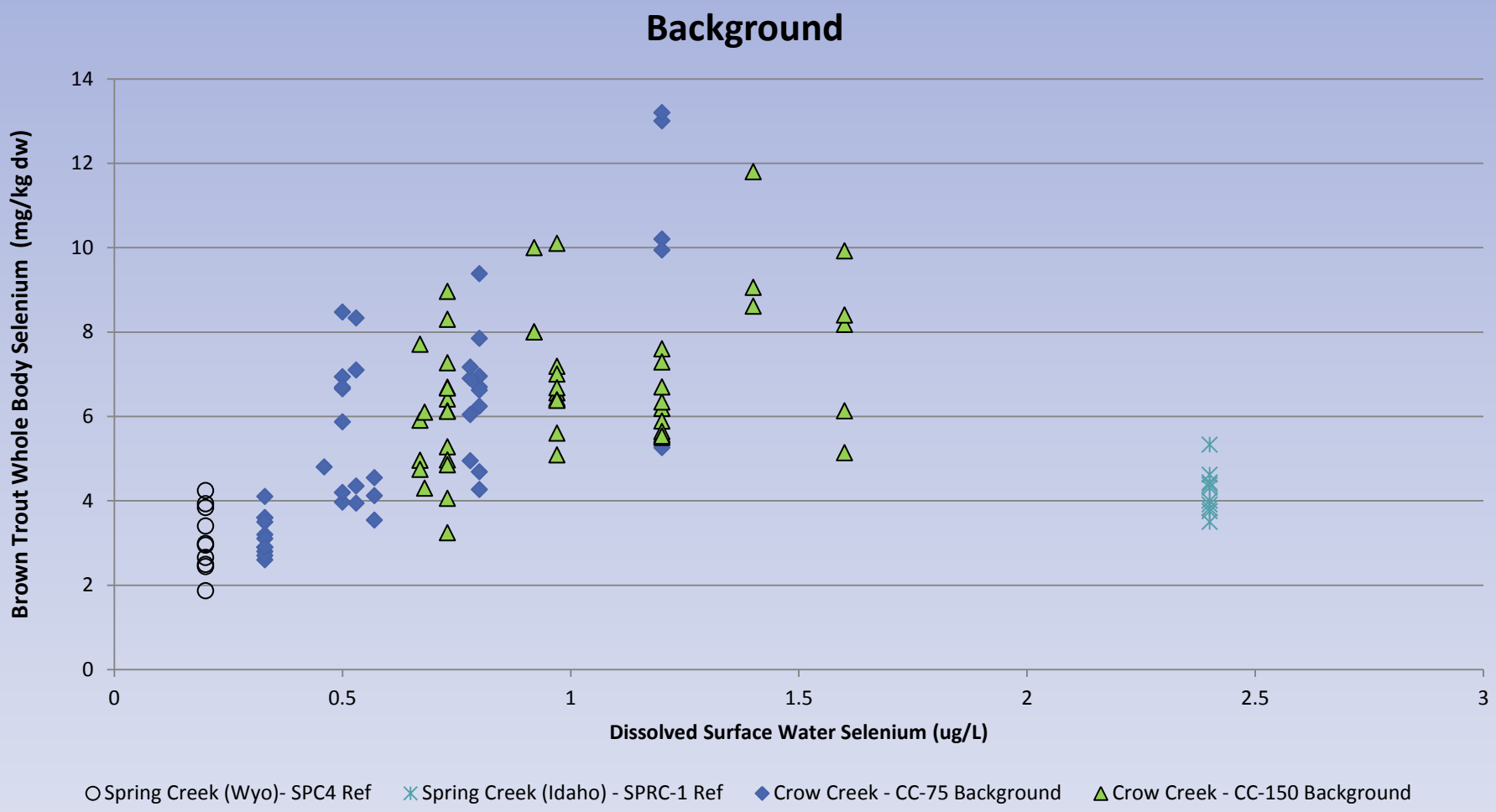
Brown Trout Whole Body Tissue and Surface Water Se Concentrations 2006 to 2011



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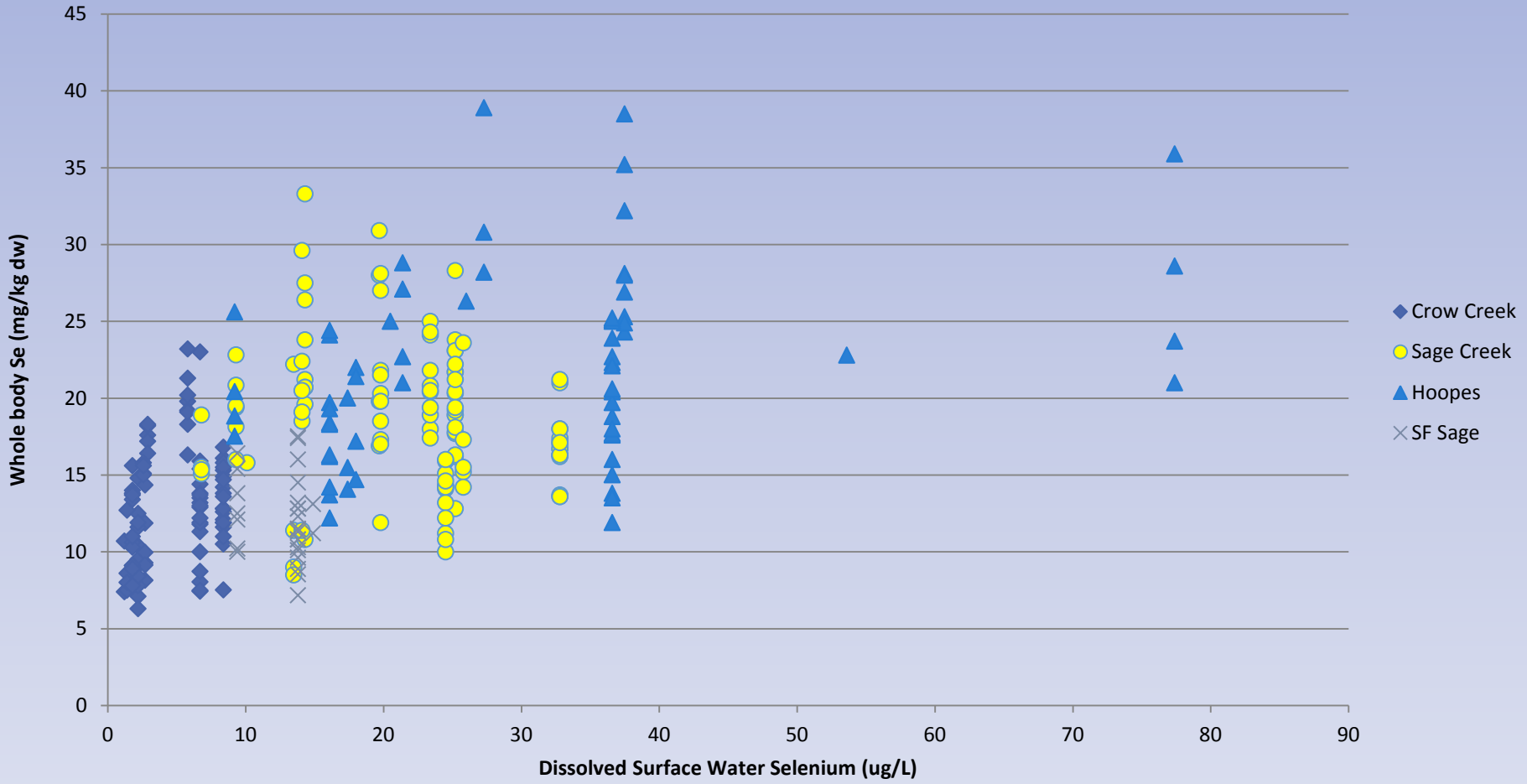

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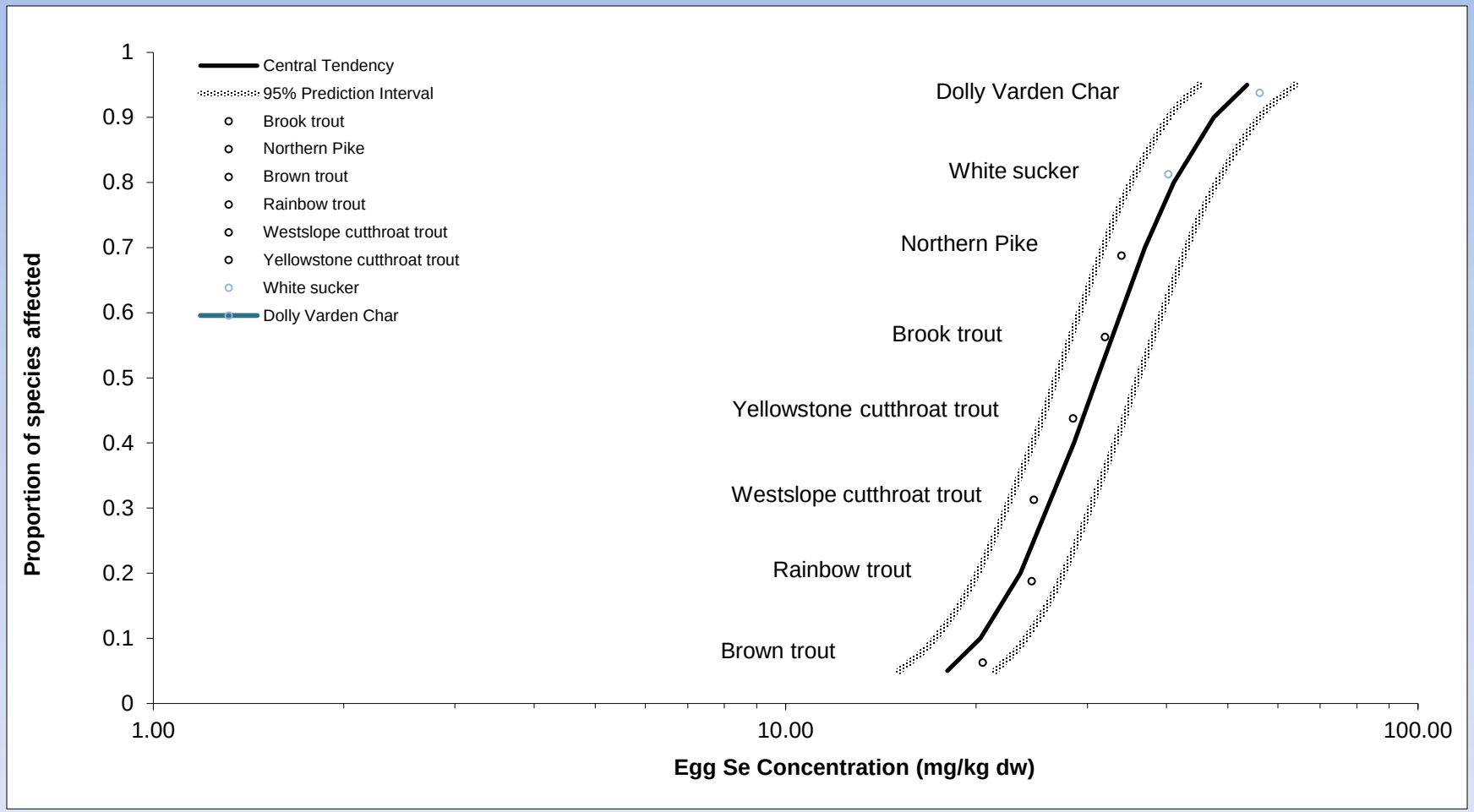
Summary of egg selenium thresholds in wild fish from coldwater systems

Species	Source Study	Adult Exposure	Endpoint	Tissue	Endpoint Statistic	Selenium (µg/g dry weight)	Statistic Derivation Source
Brown Trout	Formation Environmental (2012)	Field	Alevin survival	Egg	EC10	20.5	a
Brown Trout	USEPA interpretation of Formation Environmental (2012)	Field	Alevin survival	Egg	EC10	21	b
Brook Trout	Holm et al. 2005	Field	Larval deformities	Egg	NOEL	>48.7	b,c
Brook Trout	Holm et al. 2005	Field	Larval survival	Egg	EC10	32	a
Rainbow Trout	Holm 2002; Holm et al. 2003; Holm et al. 2005d	Field	Larval deformities	Egg	EC10	24.5	b
Yellowstone Cutthroat Trout	Hardy 2005; Hardy 2010	Lab	Larval deformities/ survival	Egg	NOEL	>16.04	b,c
	Formation Environmental (2012)	Field	Alevin survival and normal	Egg	EC10	28.5	a
Westslope Cutthroat Trout	Kennedy et al. 2000	Field	Larval deformities/ survival	Egg	NOEL	>21	c
	Rudolph et al. 2008	Field	Alevin survival	Egg	EC10	24.7	b
	Nautilus 2011; Elphick et al. 2009	Field	Alevin survival	Egg	EC10	27.7	b
Dolly Varden Char	Golder 2009e; McDonald et al. 2010	Field	Larval deformities	Egg	EC10	56.2	b
Northern Pike	Muscatello et al. 2006	Field	Larval deformities	Egg	EC24	34	b
White Sucker	de Rosemond et al. 2005	Field	Larval deformities	Egg	NOEL	40.3	b

Original table Source: Selenium Tissue thresholds - Tissue Selection Criteria, Threshold Development Endpoints, and Potential to Predict Population or Community Effects in the Field (NAMC 2009)

Fish Species Sensitivity Distribution



Deriving Criterion Elements

USEPA 2016 Derivation of Egg Criterion

		Rank	Common name	Genus	GMCV	
		15		waived1	--	
		14		waived1	--	
		13	Oligochaete	Lumbriculus variegatus	169.4	
		12	Dolly Varden	Salvelinus malma	56.2	
		11	Rotifer	Brachionus calyciflorus	45.8	
		10	Mosquitofish	Gambusia2	>13.38 WB	
		9	Fathead minnow	Pimephales promelas2	<25.6	
		8	Northern Pike	Esox lucius	34	
		7	Mayfly	Centroptilum triangulifer	29.3	
		6	Desert Pupfish	Cyprinodon macularius	27	
		5	Largemouth bass	Micropterus salmoides	26.3	
		4	Cutthroat Trout	Oncorhynchus	25.3	
		3	Brown Trout	Salmo trutta	21	
		2	Bluegill sunfish	Lepomis macrochirus	20.6	
		1	White sturgeon	Acipenser transmontanus	15.6	
	Input					
N	GMCV	Rank	ln(GMCV)	ln(GMCV)2	P=R/(N+1)	sqrt(P)
15	25.3	4	3.23	10.44	0.250	0.500
	21	3	3.04	9.27	0.188	0.433
	20.6	2	3.03	9.15	0.125	0.354
	15.6	1	2.75	7.55	0.063	0.250
		Sum:	12.05	36.41	0.63	1.54
					S2 =	3.43
					S =	1.85
					L =	2.30
					A =	2.71
					Chronic Criterion (mg/kg dw)	**15.1**

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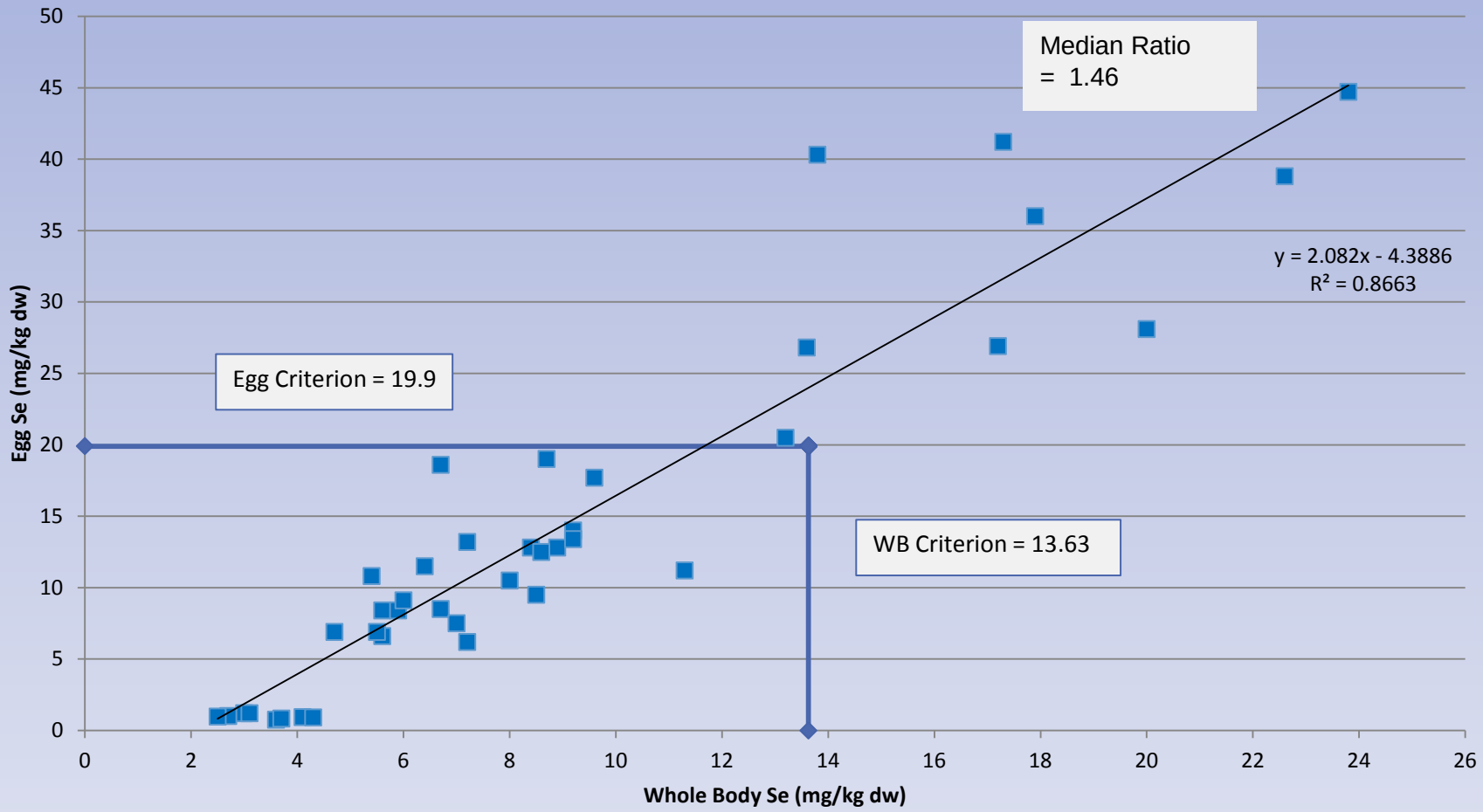
Simplot Derivation of Egg SSSC

Rank	Common name	Species	SMCV
14		waived1	--
13		waived1	--
12	Oligochaete	Lumbriculus variegatus	169.4
11	Rotifer	Brachionus calyciflorus	45.8
10	African clawed frog	Xenopus laevis	44.9
9	White Sucker	Catostomus commersonii	40.3
8	Fathead minnow	Pimephales promelas3	38.73
7	Brook Trout	Salvelinus malma	32
6	Mayfly	Centroptilum triangulifer	29.3
5	Slimy Sculpin	Cottus cognatus2	>22
4	Yellowstone Cutthroat Trout	Oncorhynchus clarkii bouvieri	28.39
3	Westslope Cutthroat Trout	Oncorhynchus clarkii	26.2
2	Rainbow Trout	Oncorhynchus mykiss	24.5
1	Brown Trout	Salmo trutta	20.5

	Input					
N	SMCV	Rank	ln(SMCV)	ln(SMCV)2	P=R/(N+1)	sqrt(P)
14	28.39	4	3.35	11.20	0.267	0.516
	26.2	3	3.27	10.67	0.200	0.447
	24.5	2	3.20	10.23	0.133	0.365
	20.5	1	3.02	9.12	0.067	0.258
		Sum:	12.83	41.22	0.67	1.59
					S2 =	1.56
					S =	1.25
					L =	2.71
					A =	2.99
					Chronic Criterion (mg/kg dw)	**19.9**

Relationship of Brown Trout Egg and Whole Body Selenium Concentrations and the Egg to Whole Body Conversion Factor



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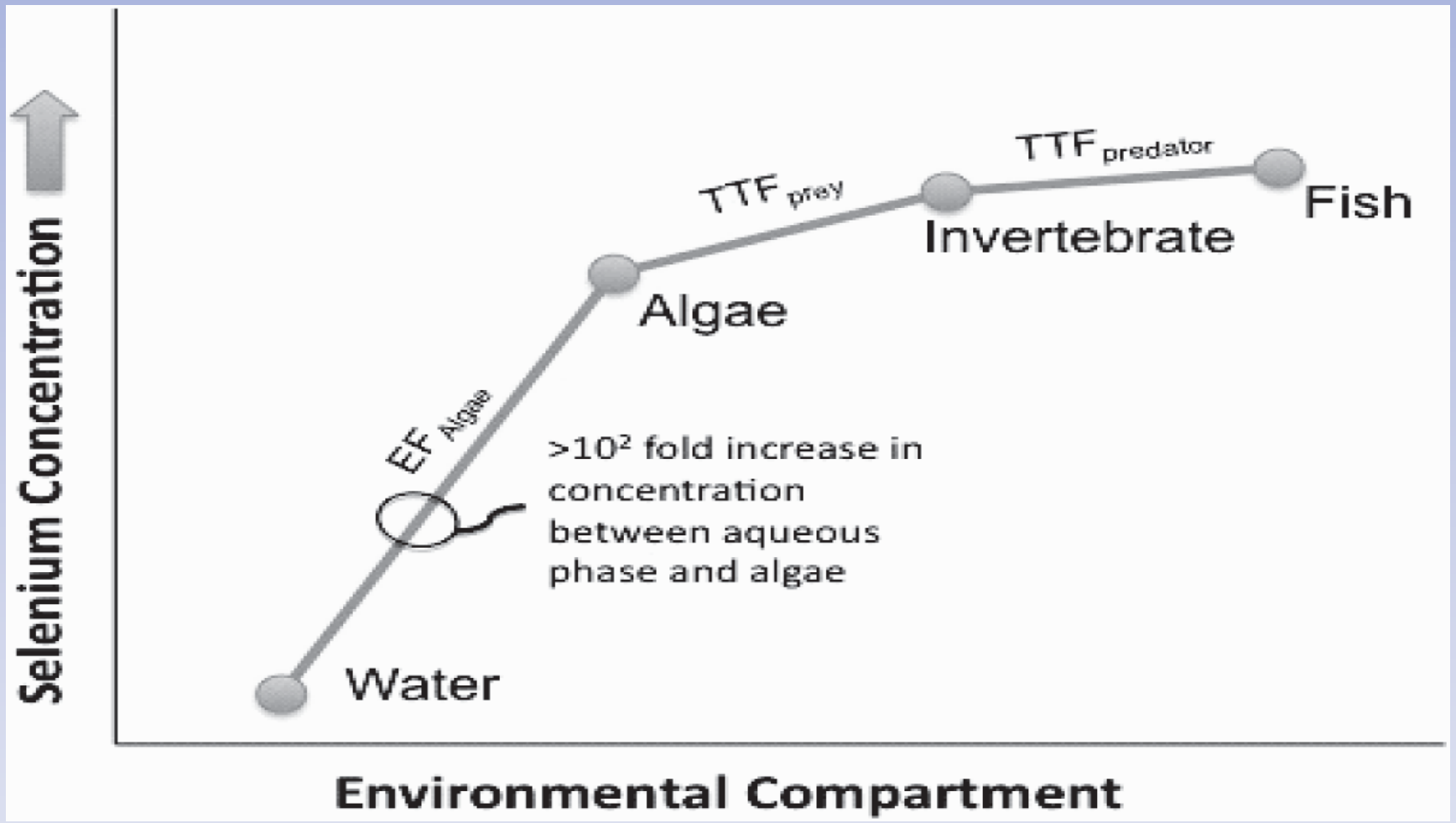
General Enrichment and Trophic Transfer Model (Luoma and Presser 2009)

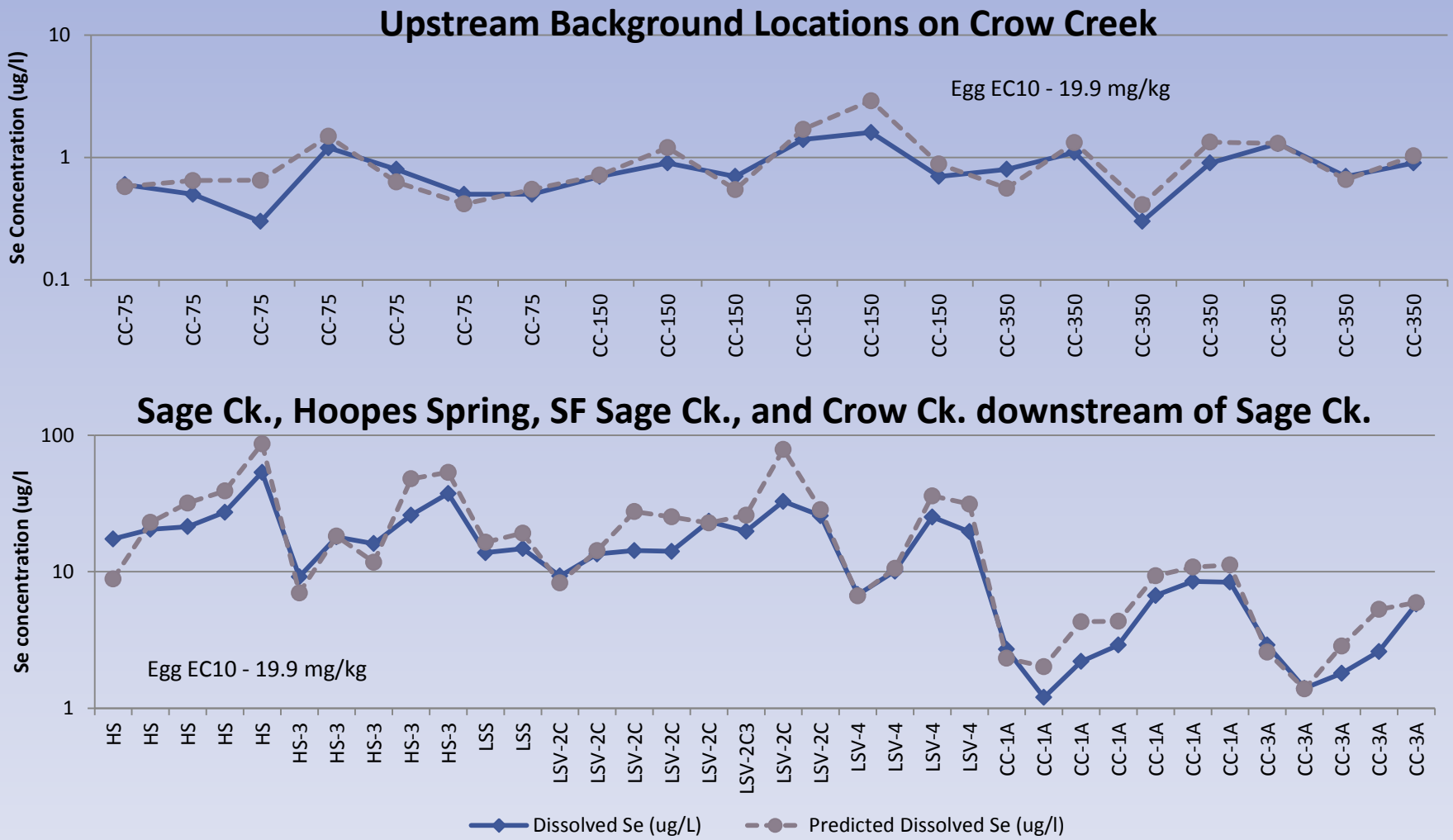


Derivation of Water Threshold using the Mechanistic Model

- $C_{water} = \frac{C_{egg}}{TTF_{composite} \; x \; EF \; x \; CF}$

  - C_{water} = predicted dissolved water concentration of selenium (micrograms per liter [ug/L])
  - C_{egg} = target egg selenium criterion (19.9 mg/kg dw)
  - EF = selenium concentration (mg/kg dw) in particulate materials / dissolved selenium concentration in water
  - CF = Whole body to egg conversion factor (1.46)

Measured Dissolved Selenium versus Predicted Dissolved Selenium Derived Using the Mechanistic Trophic Model



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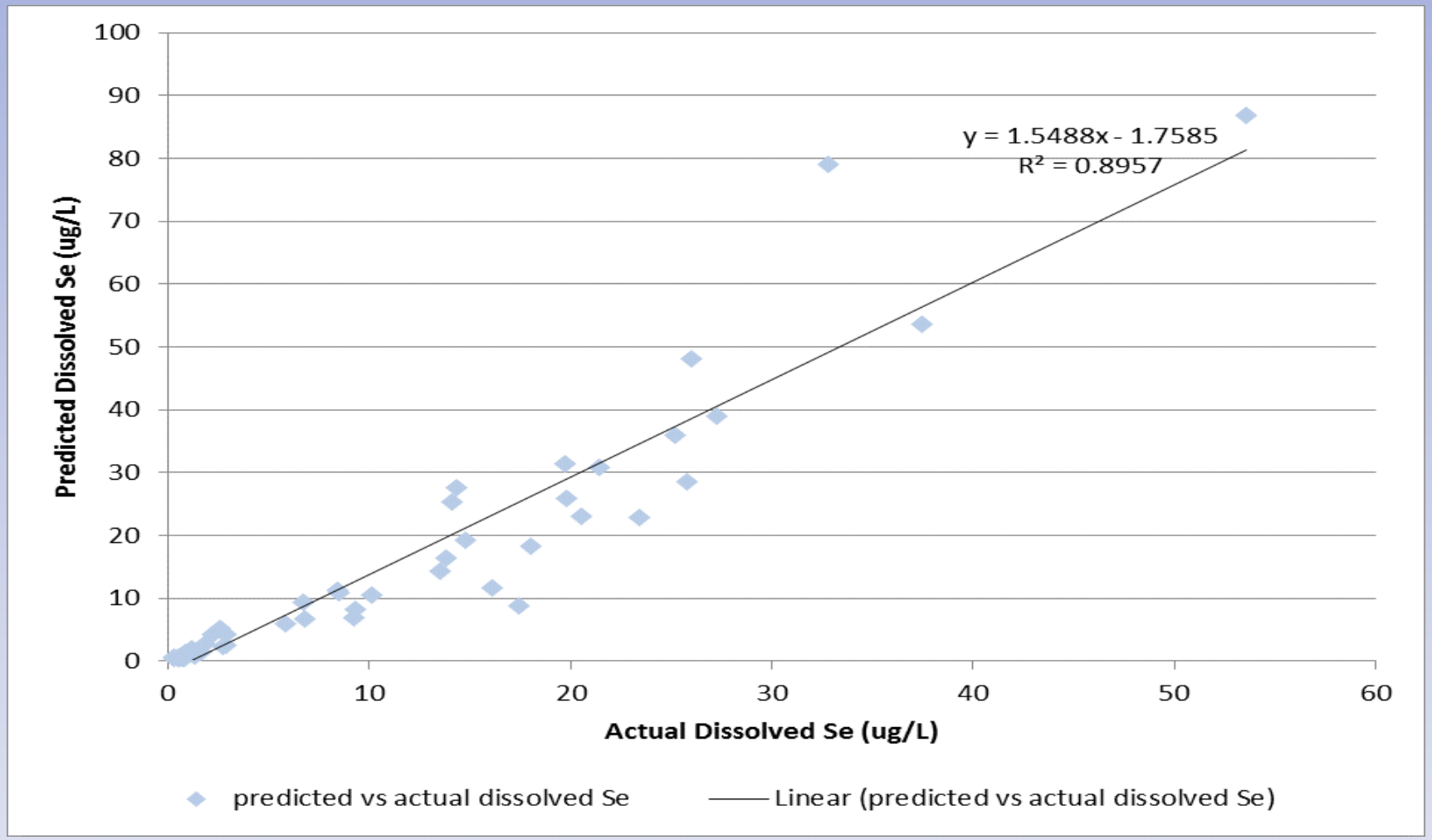
Relationship of Predicted vs Actual Dissolved Selenium Concentrations Derived from Mechanistic Trophic Model Approach



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Derivation of Water Threshold using Empirical BAF Model

- $BAF_{egg} = \frac{C_{WB\ tissue} * CF}{C_{water}}$

  - $C_{WB\ tissue}$ = concentration of selenium in whole body tissues (milligrams per kilogram dw weights)
  - C_{water} = dissolved concentration of selenium in water (ug/L)
  - CF = Whole body to egg conversion factor (1.46)

- *$C_{water\ threshold}$ = Egg Criterion (19.9 mg/kg dw)/ Median BAF_{egg}*

Proposed Criteria

Media Type	Fish Tissue[1]		Water Column[45]	
Criterion Element	Egg/Ovary[2]	Fish Whole Body[3]	Monthly Average Exposure	Intermittent Exposure[7]
Magnitude	**19.9 (mg/kg dw) egg**	**13.63 (mg/kg dw) whole body**	**13.55 (µg/L) in lotic aquatic systems**	$WQC_{int} = WQC_{30day} - C_{background}(1 - f_{int}) / f_{int}$
Duration	Instantaneous measurement	Instantaneous measurement	30 days[6]	Number of days/month with an elevated concentration
Frequency	Not more than once in three years on average	Not more than once in three years on average	Not more than once in three years on average	Not more than once in three years on average

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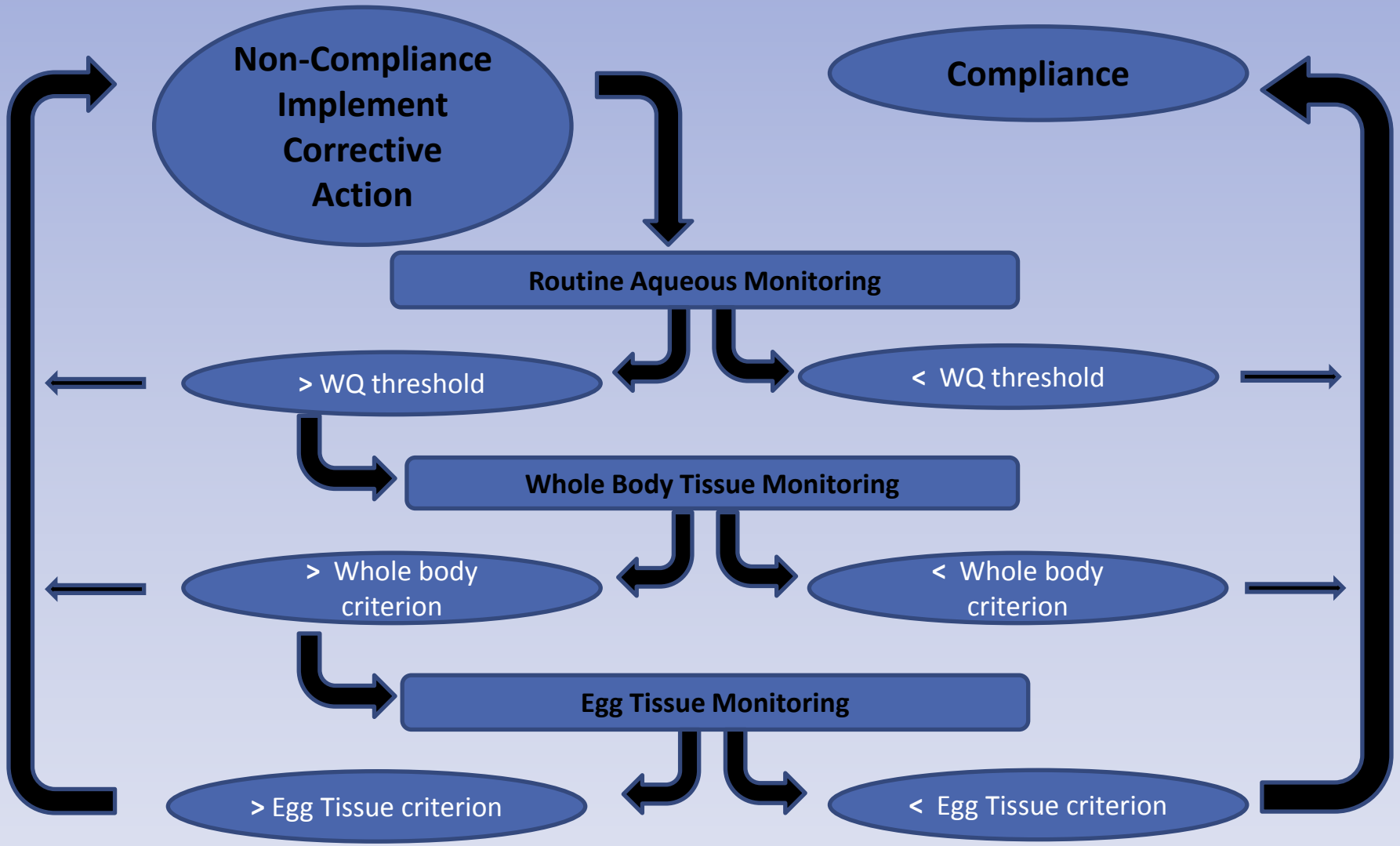
Implementing Site Specific Criterion



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Thanks for Listening
Questions/Comments?

Additional Material

EFs Drive the Model

- Presser and Luoma (2010) define EF as a partition descriptor for selenium from the aqueous to particulate fractions (e.g., algae, detritus, and sediments).

$$EF = C_{particulate} / C_{water}$$

$C_{particulate}$ = selenium concentration in algae (periphyton), detritus, and/or sediments

C_{water} = selenium concentration in surface water (dissolved concentration)

TTFs

- $TTF_{invertebrate} = C_{invertebrate}/C_{particulate}$
  - $C_{particulate}$ for benthos from this Site derived as: 10% sediment Se concentration plus 90 % algae Se concentration for each location.
  - Allowed for a derivation of $TTF_{invertebrate}$ for each location.
- $TTF_{sculpin} = C_{sculpin}/C_{invertebrate}$
  - $C_{sculpin}$ - mean concentration of Se in sculpin tissues from each location
  - $C_{invertebrate}$ - concentration of Se in invertebrates for each location.
- $TTF_{trout} = C_{trout}/\left(0.5 \times C_{sculpin}\right) + \left(0.5 \times C_{invertebrate}\right)$
  - C_{trout} = mean selenium concentration in brown trout from a location and time period
  - $C_{sculpin}$= mean selenium concentration in sculpin (mg/kg dw) from the same location and time period
  - $C_{invertebrate}$ = selenium concentration in benthic invertebrates (mg/kg dw) from the same location and time period

TTF composite

$$TTF_{composite} = TTF_{trout} \times TTF_{sculpin} \times TTF_{invertebrate}$$

- TTF trout derived to account for the diet of brown trout
- Literature indicates a mixed diet of invertebrates and fish

Mechanistic Trophic Model vs Empirical BAF Model

Data Grouping	Variables						Mechanistic Model Predicted Selenium Concentration in water (µg/L)	Empirical BAF Predicted Selenium Concentration in water (µg/L)
	EF	TTF_{invert}	$TTF_{sculpin}$	TTF_{trout}	TTF_{comp}	CF	Egg Criterion = 19.9 mg/kg dw	Egg Criterion = 19.9 mg/kg dw
Site Streams, all seasons	0.48	1.89	1.08	1.08	2.20	1.46	12.99	12.34
Site Streams, summer/fall seasons	0.43	2.05	1.09	1.08	2.43	1.46	13.20	**13.28**
Hoopes Spring, all seasons	0.43	1.20	1.55	1.21	2.25	1.46	14.22	16.77
Sage Creek, all seasons	0.46	1.91	0.86	0.97	1.59	1.46	18.87	16.32
Crow Creek, all seasons	0.91	2.61	1.09	1.10	3.14	1.46	4.81	4.01
South Fork Sage Creek, all seasons	0.27	2.00	1.47	0.89	2.61	1.46	19.61	14.99
Hoopes Spring, summer/fall seasons	0.40	1.50	1.47	1.21	2.66	1.46	12.98	19.00
Sage Creek, summer/fall seasons	0.39	1.98	0.84	0.97	1.60	1.46	22.10	16.88
Crow Creek, summer/fall seasons	0.67	2.49	1.12	1.18	3.28	1.46	6.21	4.85
South Fork Sage Creek, summer/fall seasons	0.27	2.00	1.47	0.89	2.61	1.46	19.61	14.99

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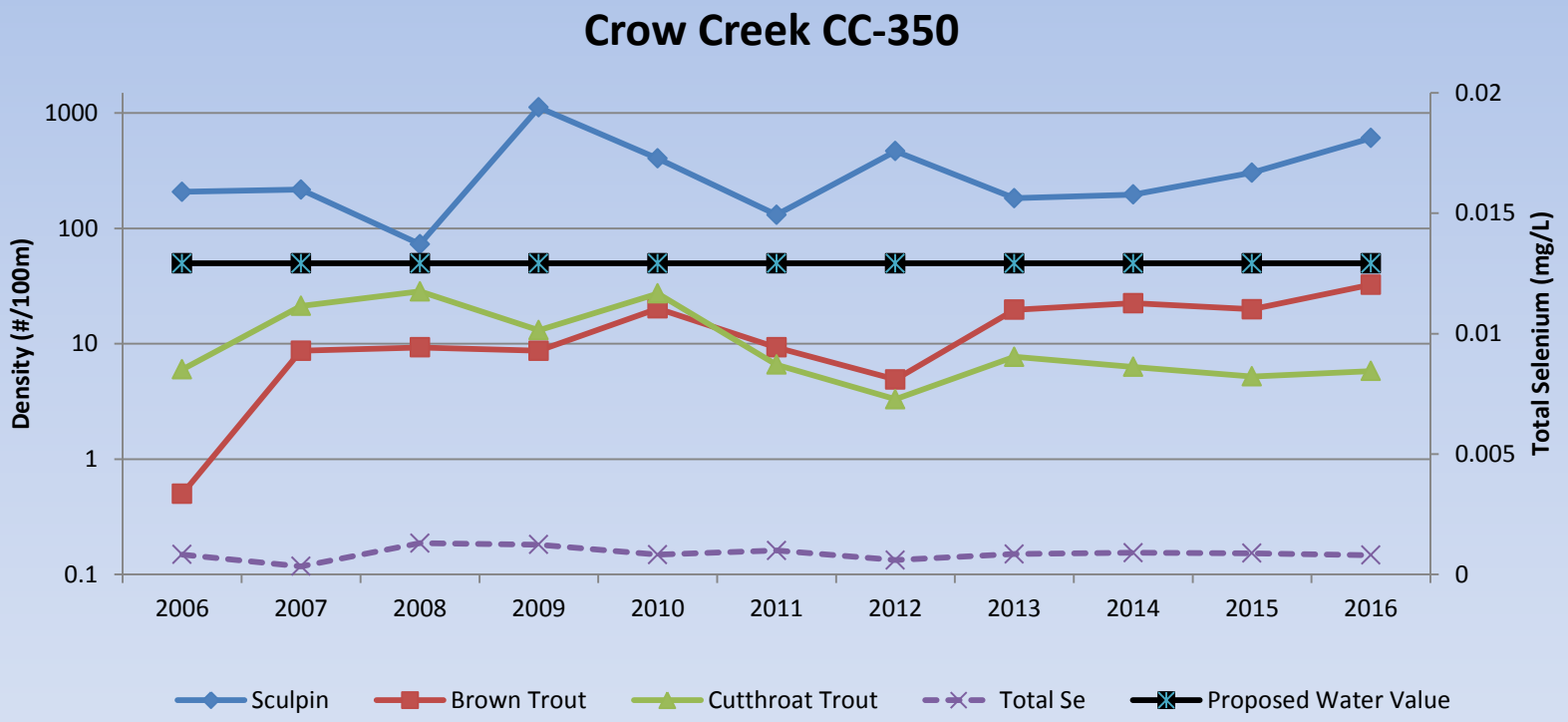
Supporting Evidence

- Multiple age classes of brown trout are present immediately downstream of Hoopes Spring, at LSV-2C, where selenium concentrations in diet and aqueous media are substantially elevated.
- Trout populations (both brown and YCT) in Sage Creek and Crow Creek downstream of Hoopes Spring are productive compared to regional averages. For example, location LSV-2C exceeds the 95th percentile catch per unit effort for Ecoregion 6 streams.
- Compared to historical trout population data from 1979, 1981, 1986, 1987, and 1999, trout population estimates in Sage Creek from 2006 and 2010 fall within the range of estimates collected prior to mining and those collected about 10 years after mining commenced.

Fish Population Density vs Total Selenium in Water through Time



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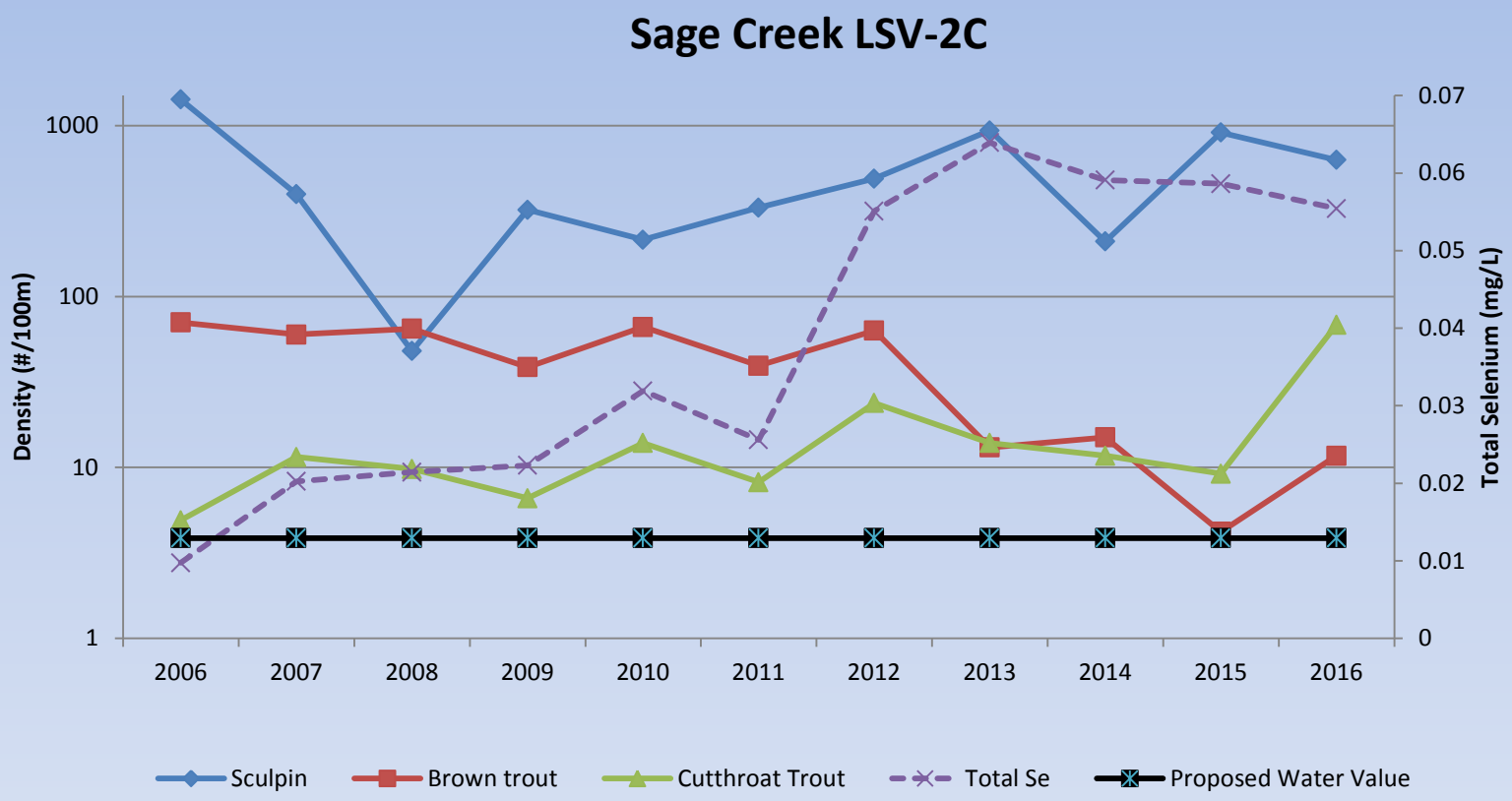

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