



Selenium Dynamics in Mining-Influenced Headwater Streams of Central Appalachia

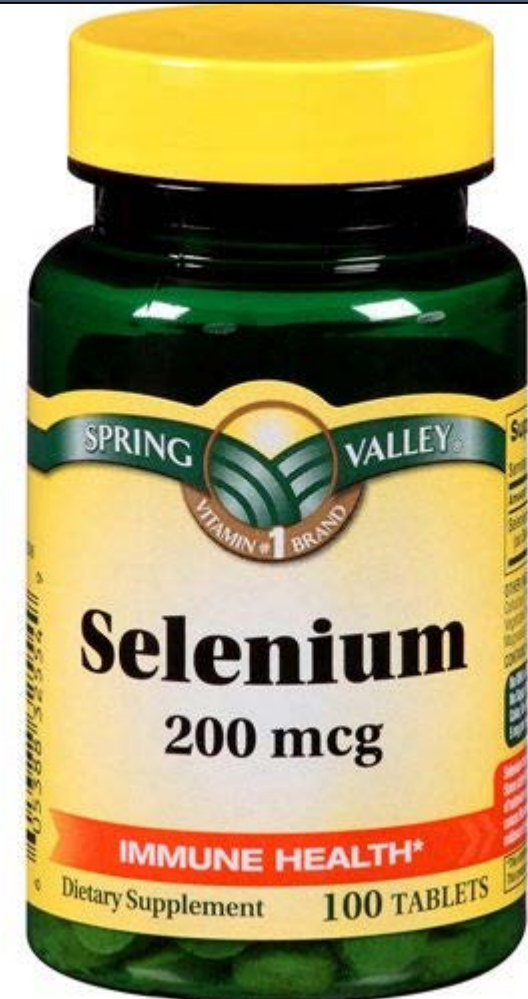
Kriddie Whitmore

Selenium: Trace Element

1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULFUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON
37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.96 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.6 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM	113 (...) Uut UNUNTRIUM	114 (287) Fl FLEROVIUM	115 (...) Uup UNUNPENTIUM	116 (291) Lv LIVERMORIUM	117 (...) Uus UNUNSEPTIUM	118 (...) Uuo UNUNOCTIUM

Selenium: “Both a Nutrient and a Poison”

- Essential to many life forms -from bacteria to humans
- Used in formation of seleno-proteins and enzymes



Selenium: “Both a Nutrient and a Poison”

- Toxic effects at only slightly elevated levels
- Effects most pronounced in egg-laying vertebrates
 - Fish, birds, reptiles & amphibians
- Juvenile deformities, reproductive failure



Case study: Belews Lake, NC

- 1973: lake began receiving Se contaminated discharge water from coal burning plant
- 19 out of 20 fish species lost in 4 years
- Se concentration in water only 10x–20x uncontaminated sites



Determining Selenium Criteria

- Challenges
 - Bioaccumulative tendency
 - Patterns of enrichment and bioaccumulation are controlled by site-specific factors
- Few studies have been conducted in Appalachia

Table 4.1. Summary of the Recommended Freshwater Selenium Ambient Chronic Water Quality Criterion for Protection of Aquatic Life.

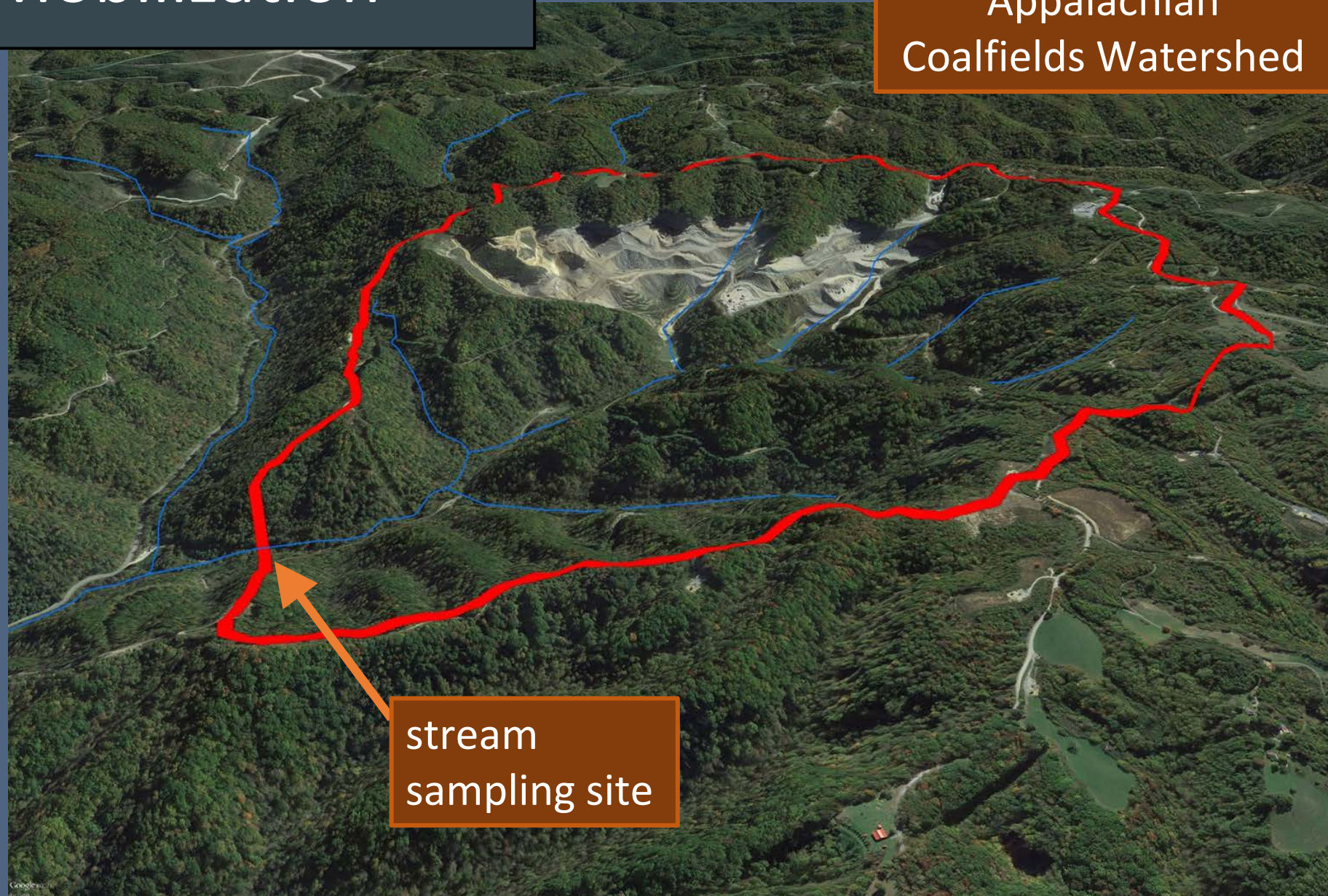
Media Type	Fish Tissue ¹		Water Column ⁴	
	Egg/Ovary ²	Fish Whole Body or Muscle ³	Monthly Average Exposure	Intermittent Exposure ⁵
Magnitude	15.1 mg/kg dw	8.5 mg/kg dw whole body <u>or</u> 11.3 mg/kg dw muscle (skinless, boneless filet)	1.5 µg/L in lentic aquatic systems 3.1 µg/L in lotic aquatic systems	$WQC_{int} = \frac{WQC_{30-day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration	Instantaneous measurement ⁶	Instantaneous measurement ⁶	30 days	Number of days/month with an elevated concentration
Frequency	Not to be exceeded	Not to be exceeded	Not more than once in three years on average	Not more than once in three years on average

Source: Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2016

Selenium Mobilization

Appalachian
Coalfields Watershed

- Se is enriched in rock deposits associated with coal seams
- Mining exposes unweathered rock to rainfall
- Se oxidizes, and becomes mobile



stream
sampling site

Selenium Enrichment

1. Dissolved Se enters stream reach

Selenium concentration

Water



Selenium Enrichment

1. Dissolved Se enters stream reach
1. Uptake by algae and microbes

Selenium concentration

Water

Algae/
Microbes

Enrichment dependent on site-specific ecosystem characteristics

- Dissolved Se speciation
- Site hydrology
- Aquatic community composition

Selenium Enrichment

1. Dissolved Se enters stream reach
1. Uptake by algae and microbes
1. Trophic transfer to consumers

Selenium concentration

Water

Algae/
Microbes

Aquatic
Invertebrate

Aquatic
Vertebrate
predator

Enrichment dependent on site-specific ecosystem characteristics

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Selenium concentration

Water

Enrichment

Algae/
Microbes

Trophic Transfer

Trophic Transfer

Aquatic
Invertebrate

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Enrichment dependent on site-specific ecosystem characteristics

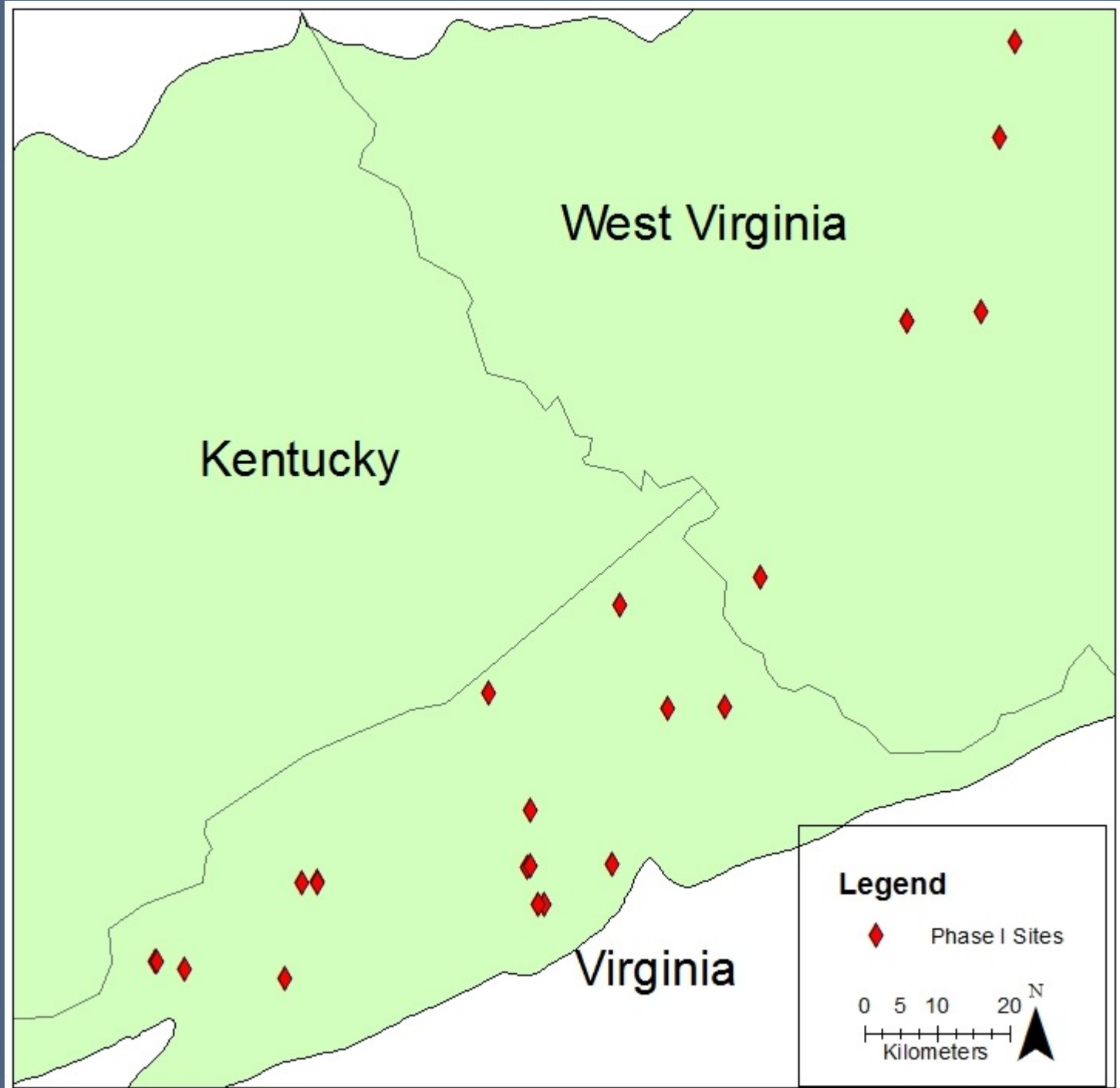
- Dissolved Se speciation
- Site hydrology
- Aquatic community composition

Research Questions

1. Is selenium enrichment and bioaccumulation occurring in headwater streams influenced by coal mining?
1. Do Se dynamics of enrichment and bioaccumulation vary among different levels of Se exposure?

Phase I

Is Selenium
bioaccumulating?



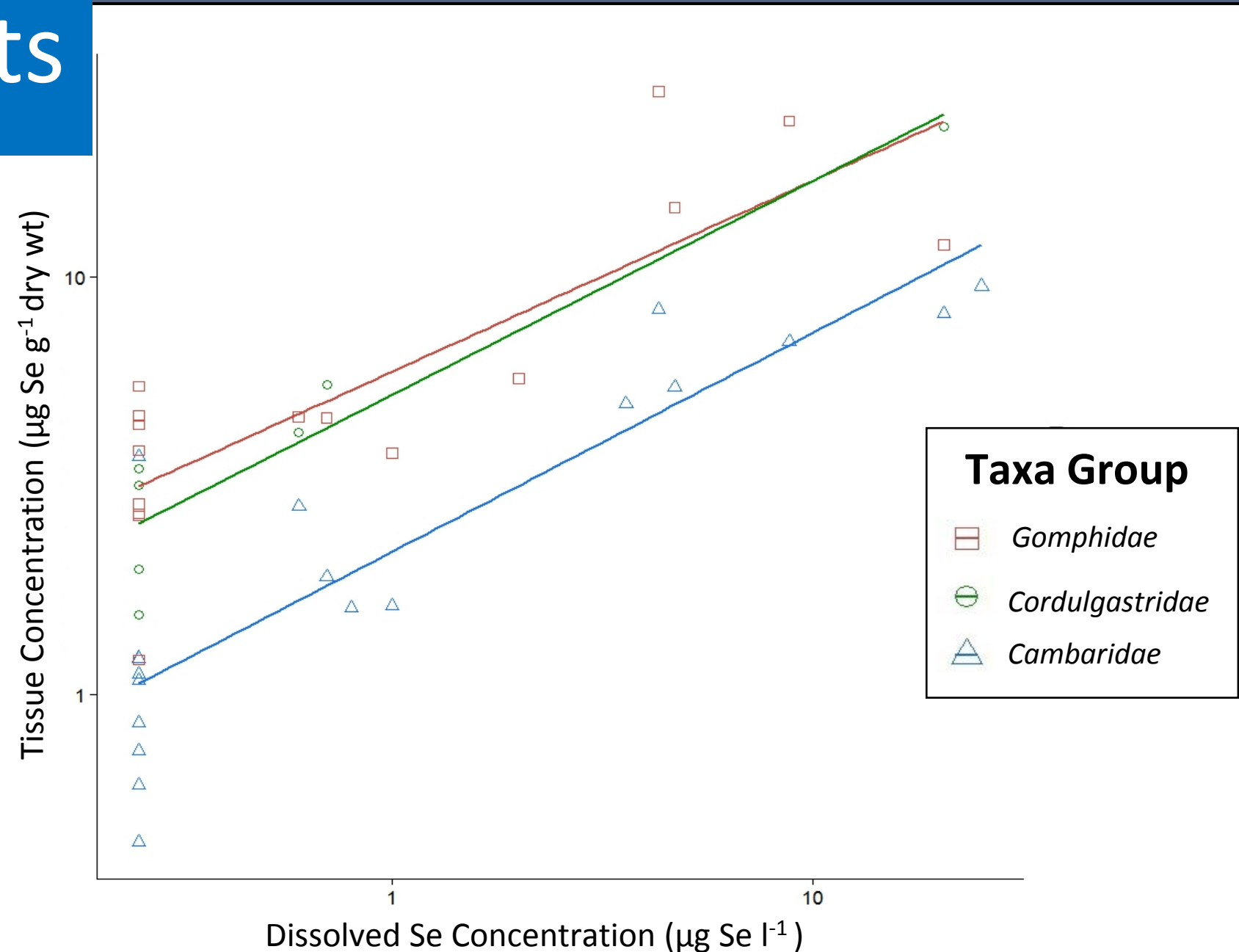
Phase I Methods

- 23 Streams
- water samples
- 2 dragonfly taxa
 - Gomphidae
 - Cordulegastridae
- Crayfish



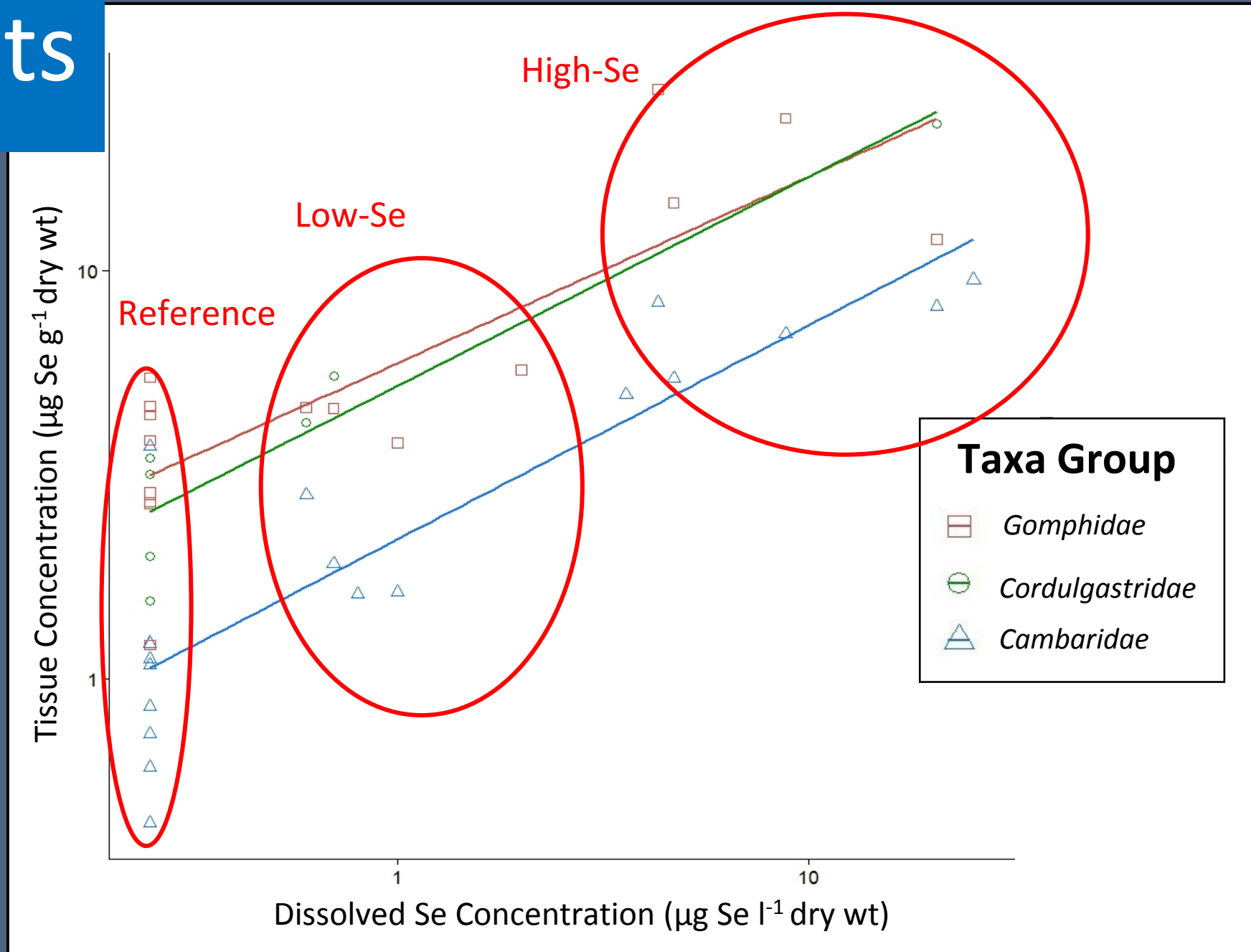
Phase I Results

- Positive relationship between dissolved Se in the water column and Se in tissue samples



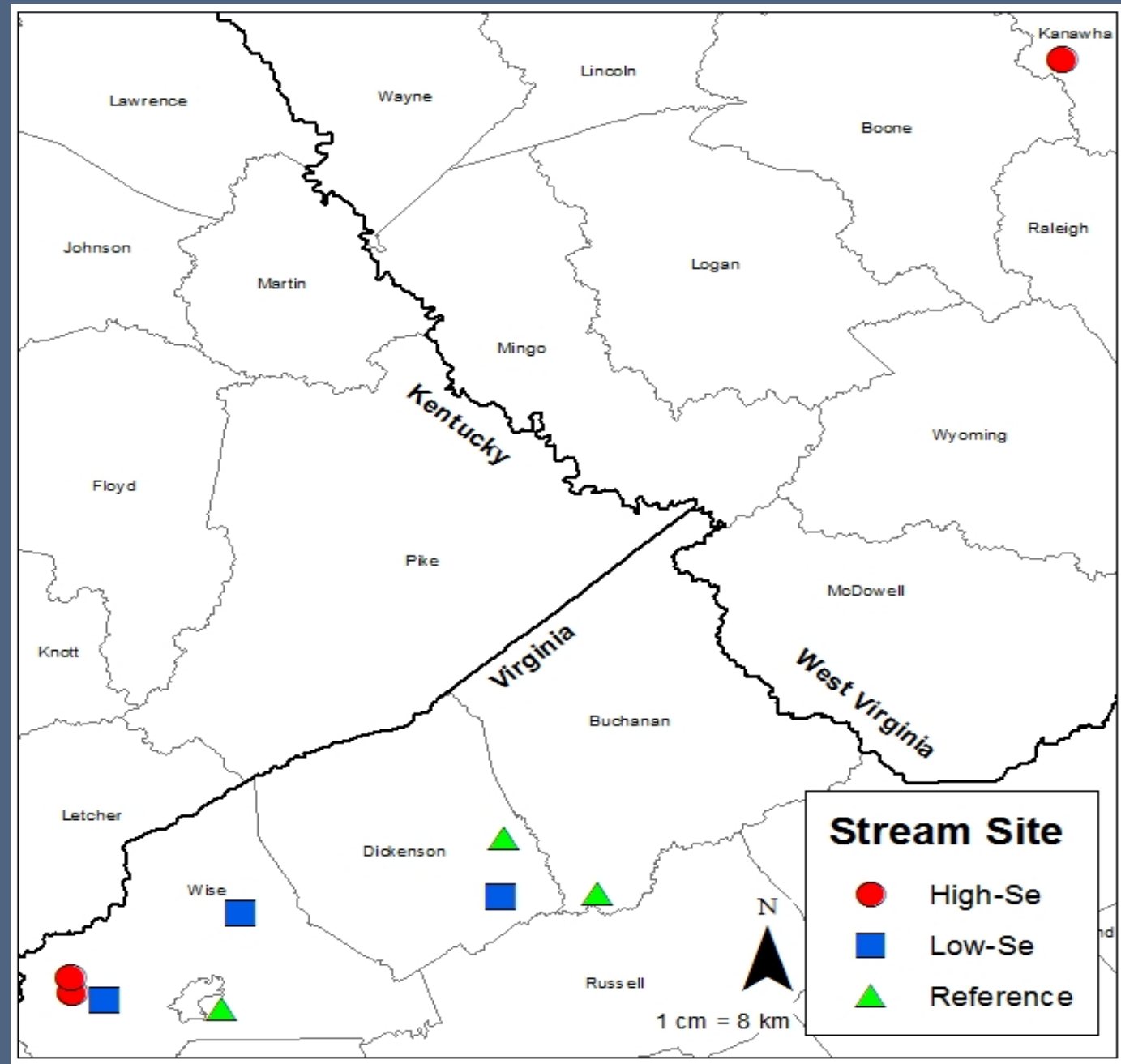
Phase I Results

- Site selection



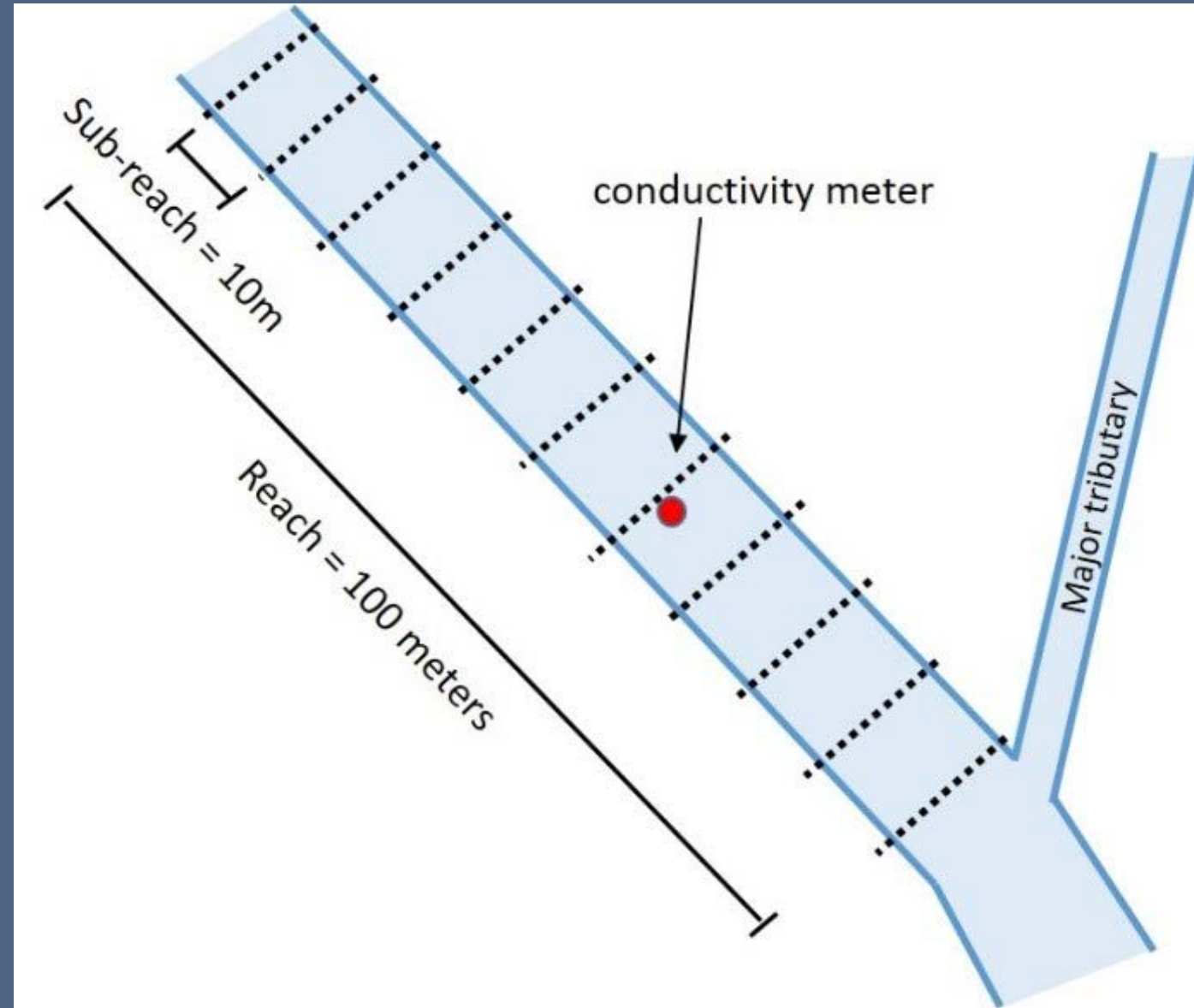
Phase II

Selenium Dynamics In Headwater Streams



Phase II Methods

- 9 streams:
 - 3 Reference, 3 Low-Se, 3 High-Se
- 2 sampling seasons
 - Fall 2015, Spring 2016



Phase II Methods

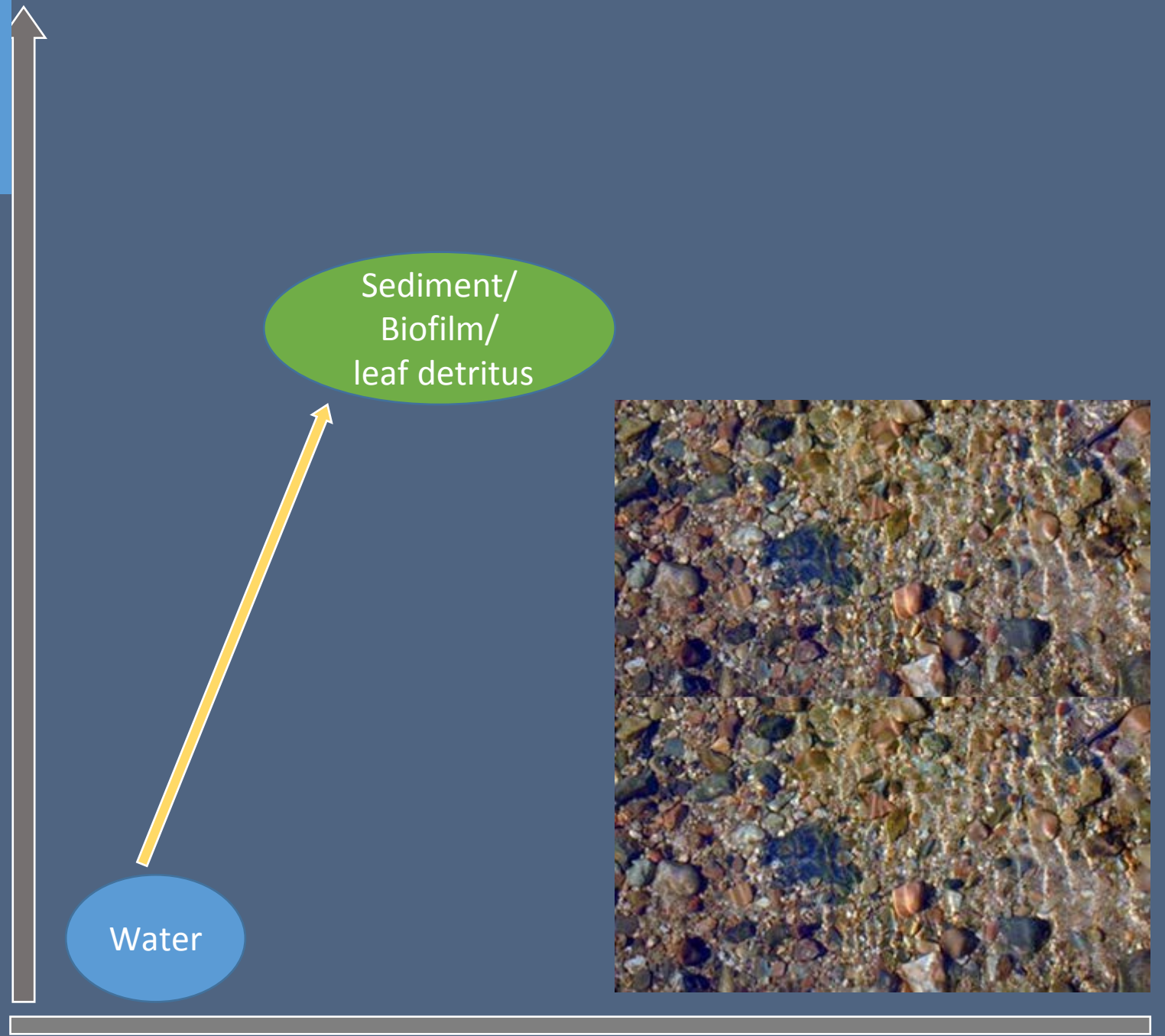
- Media Collected
 - Water-column



Water

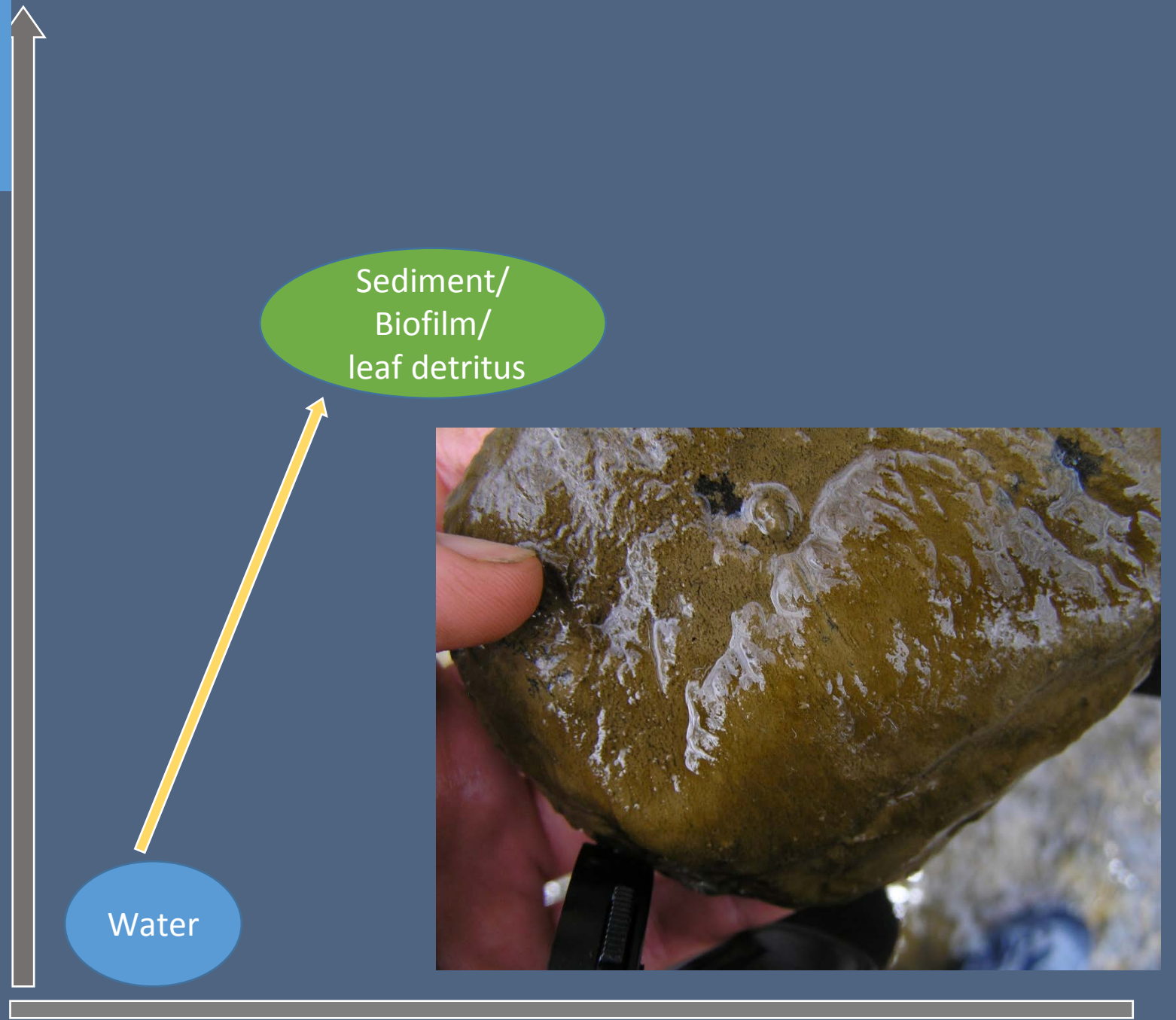
Phase II Methods

- Media Collected
 - Water-column
 - Sediment



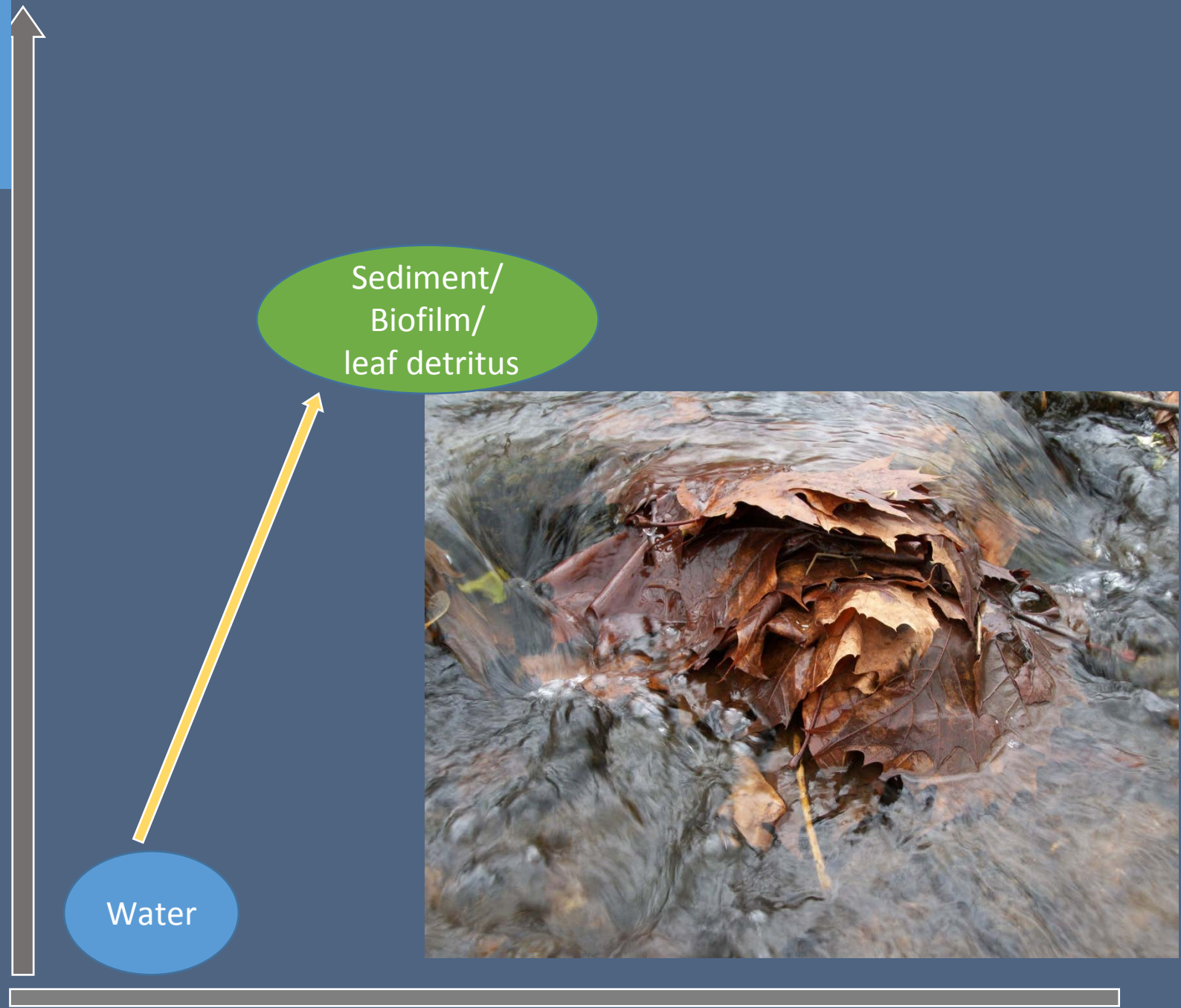
Phase II Methods

- Media Collected
 - Water-column
 - Sediment
 - Biofilm



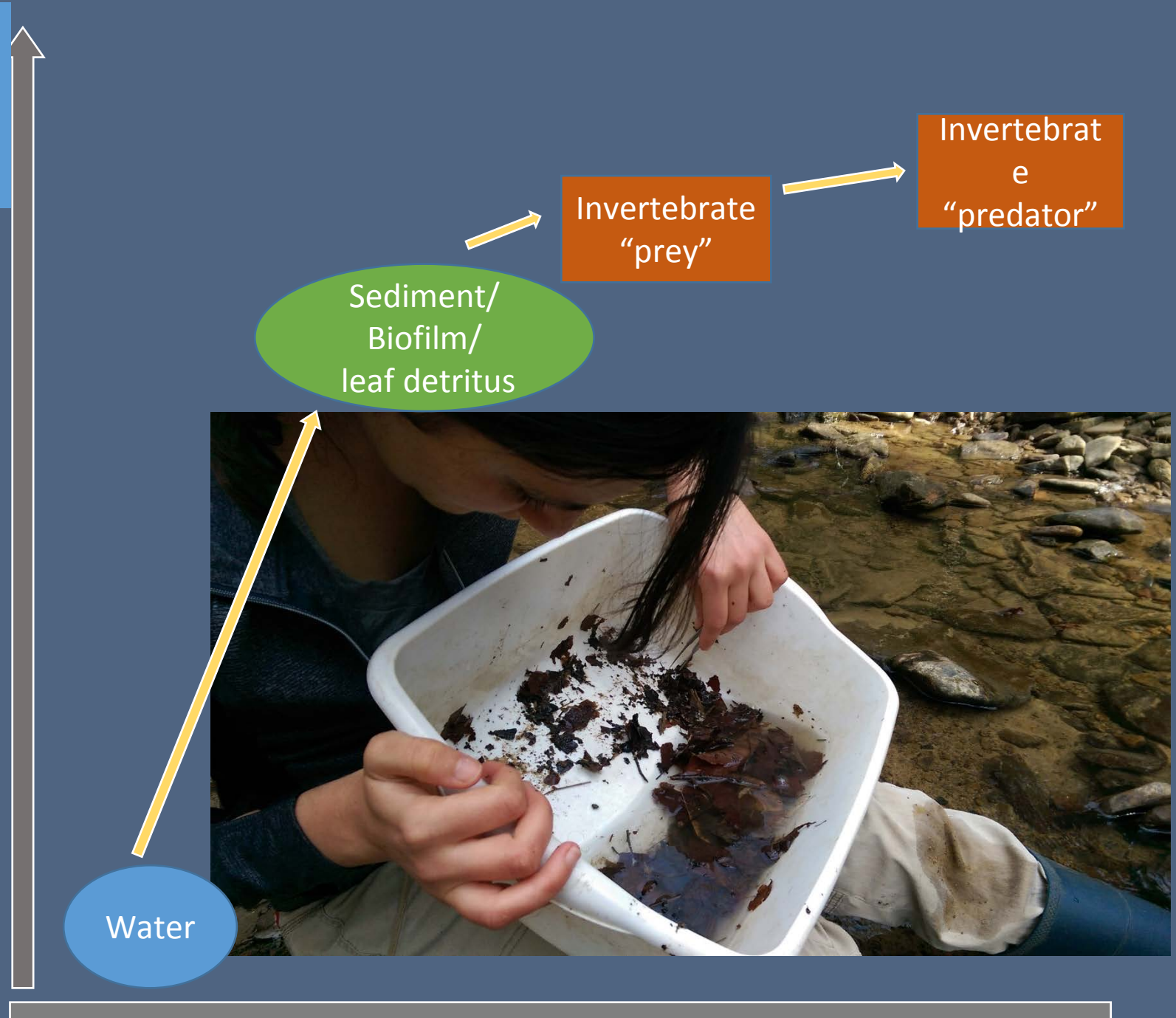
Phase II Methods

- Media Collected
 - Water-column
 - Sediment
 - Biofilm
 - Leaf detritus



Phase II Methods

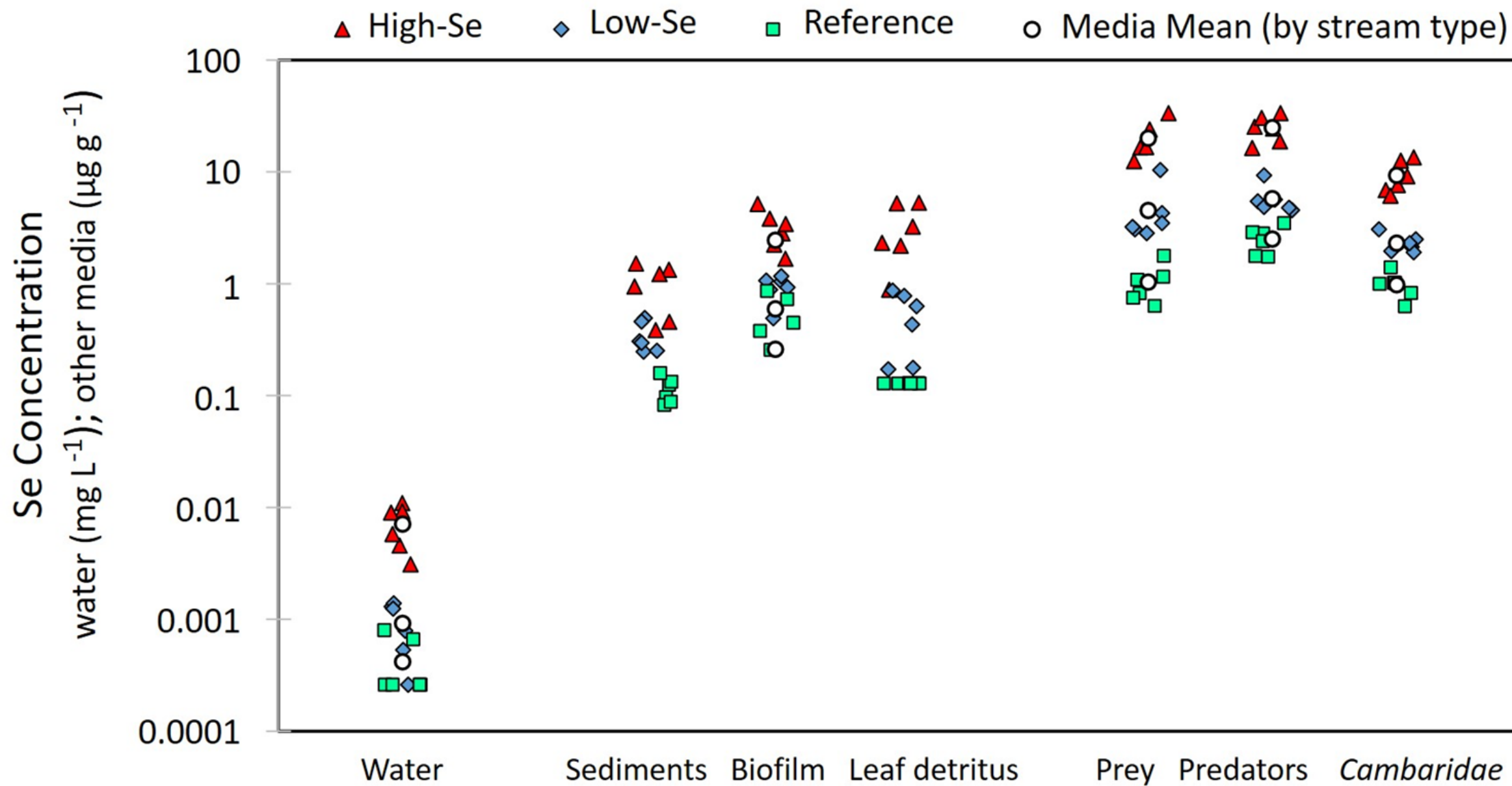
- Media Collected
 - Water-column
 - Sediment
 - Biofilm
 - Leaf detritus
- Macroinvertebrates
- Crayfish

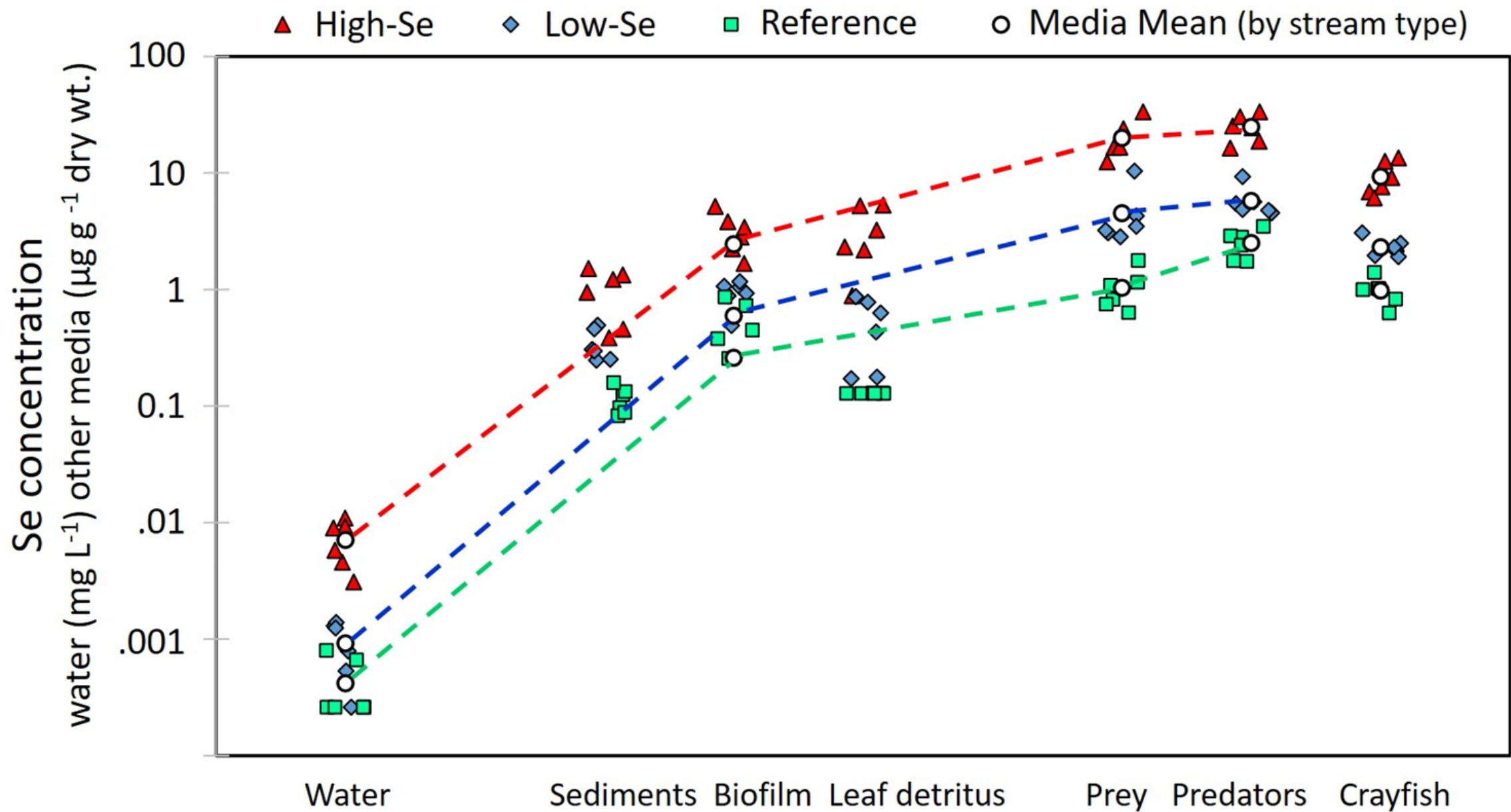


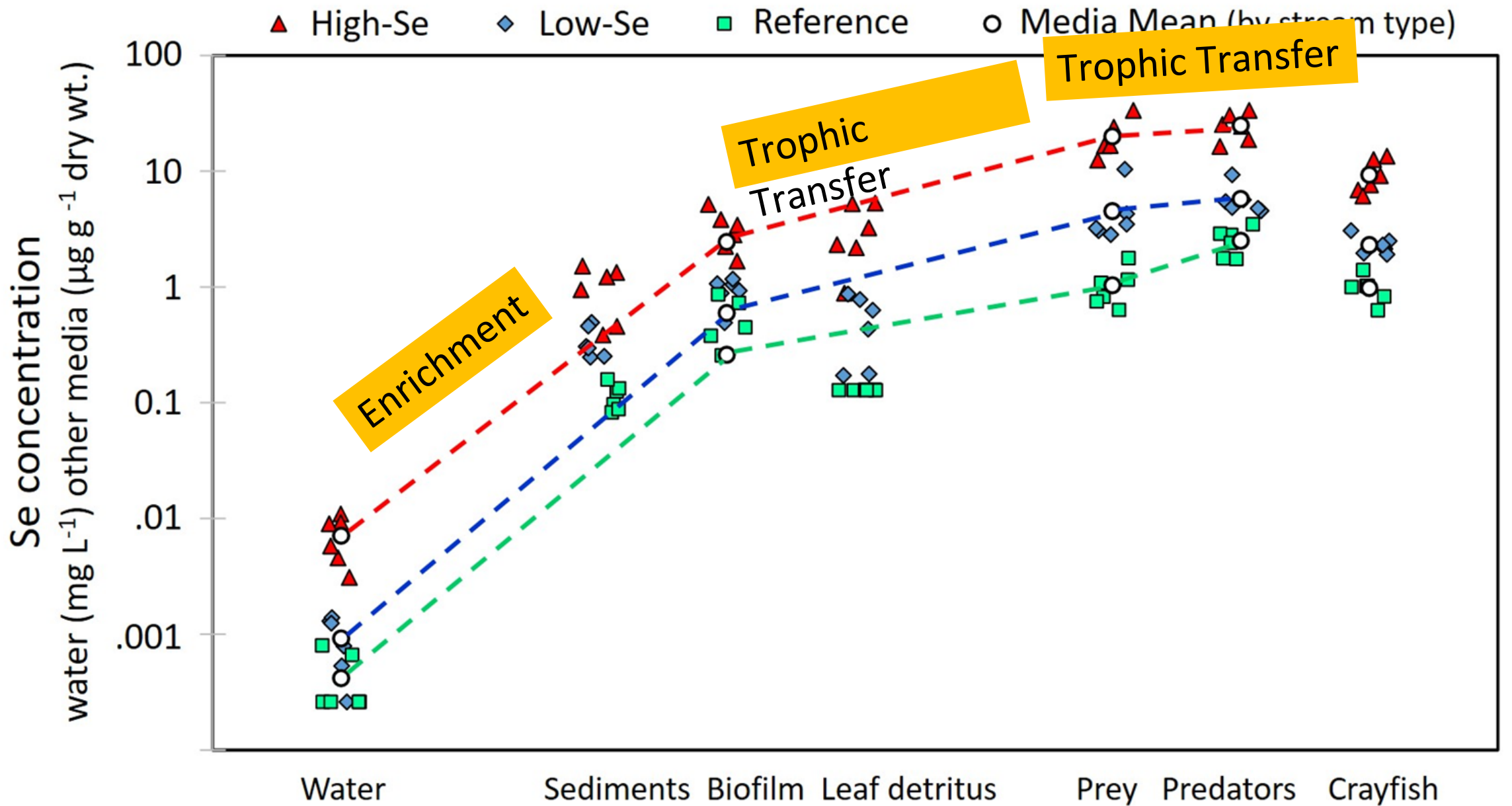
Phase II Methods

- Macroinvertebrates identified and sorted into predator/prey taxa groups
- All samples dried and ground
- Acid digestion
- Analysis on ICP-MS









Conclusions

- High Se in the water column result in high Se in the aquatic food chain
- Enrichment and trophic transfer processes are concentration independent
- Se is a potential stressor in mining-influenced headwater streams

Thanks

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- Liz Sharp
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- Alex Grieve

Technical Assistance

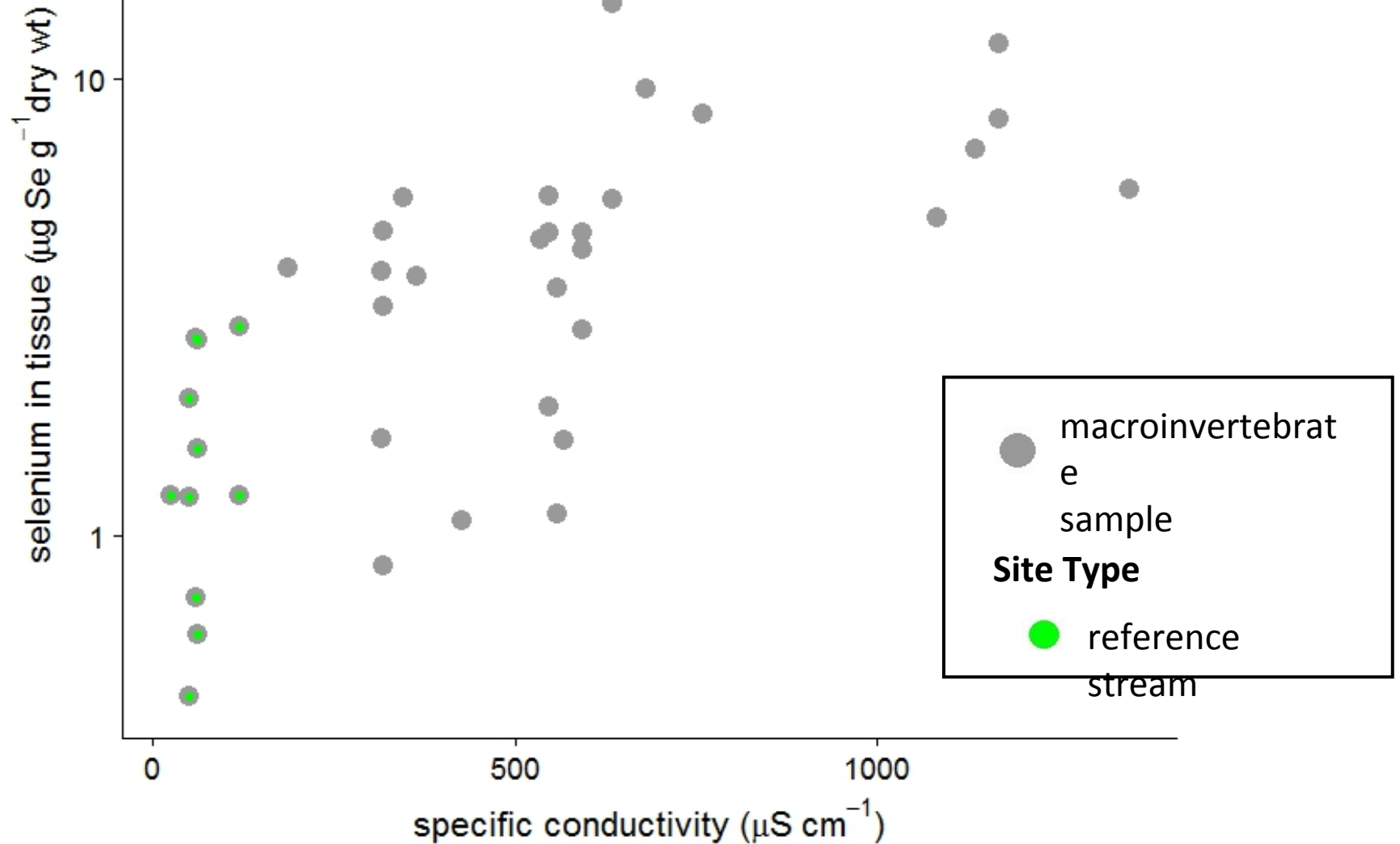
- Julie Burger
- Dave Mitchem
- Jeffery Parks
- Pat Donovan

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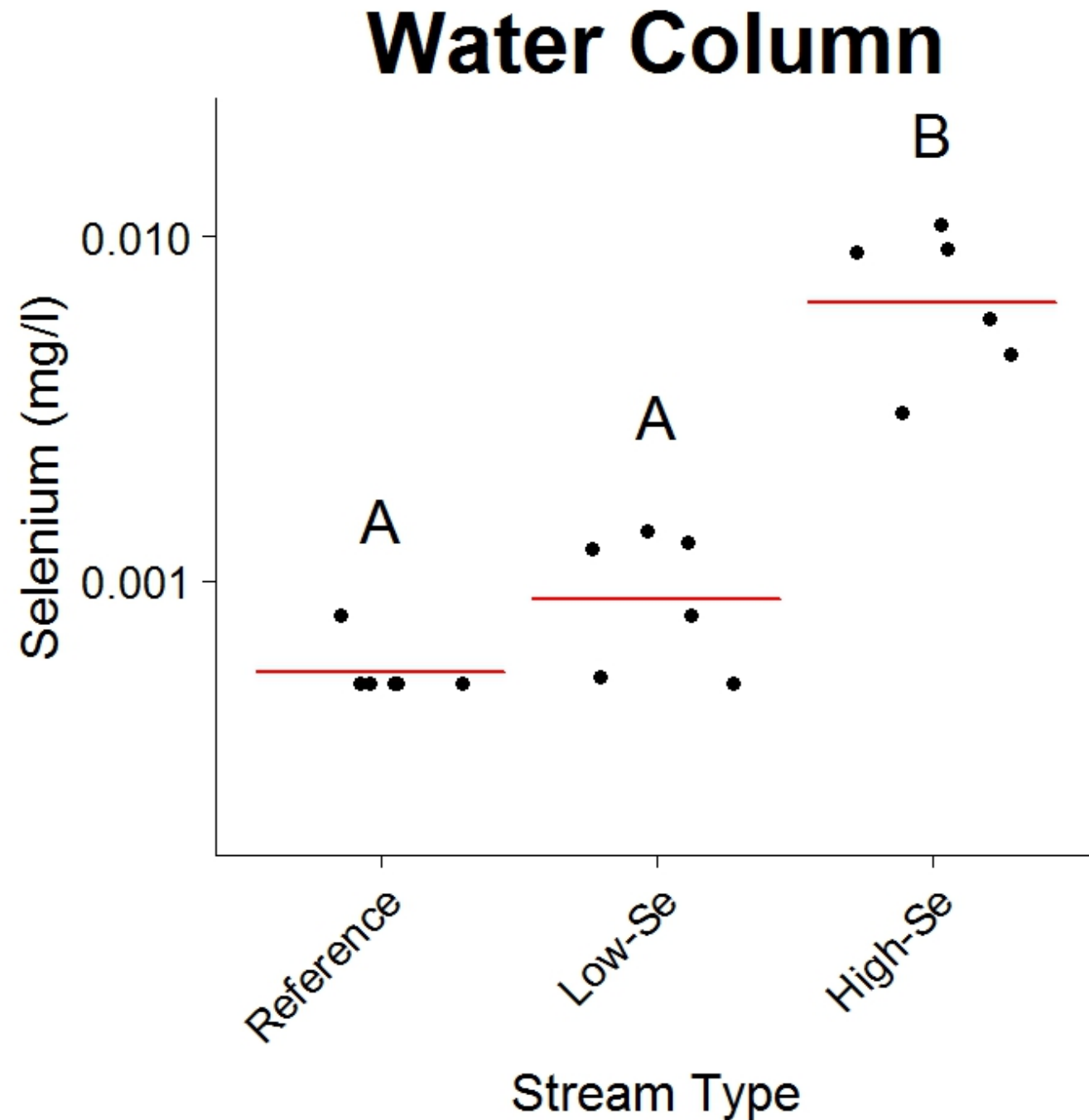
Phase I Results

- Positive relationship between conductivity and Se concentration in tissue samples
- Macroinvertebrate Se concentrations in mining-influenced streams tend to exceed those in reference streams



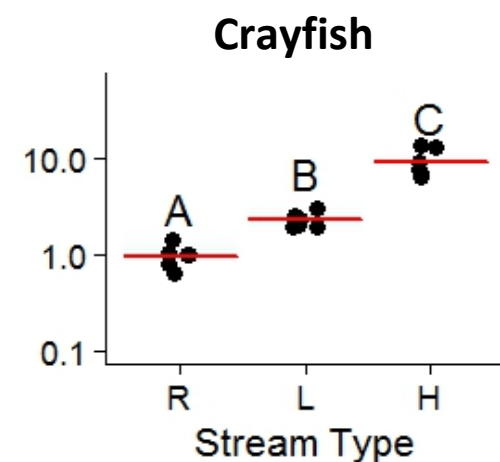
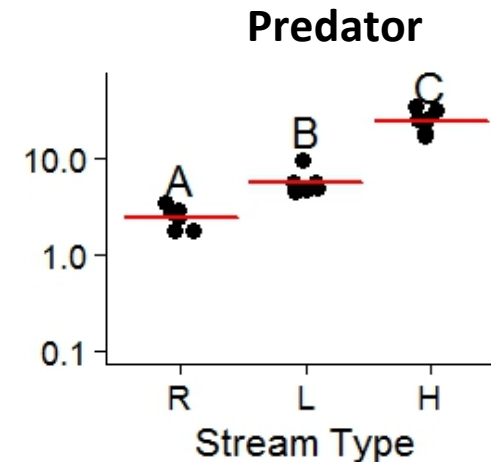
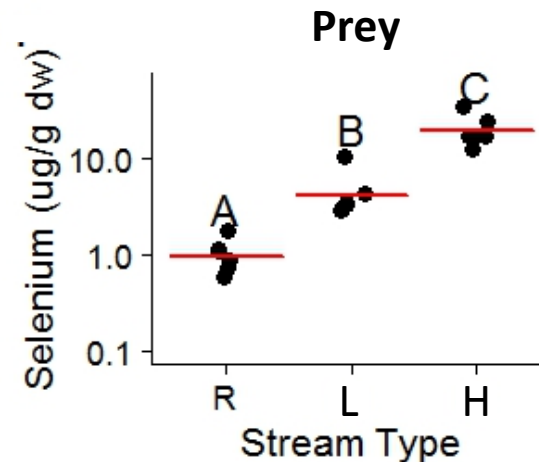
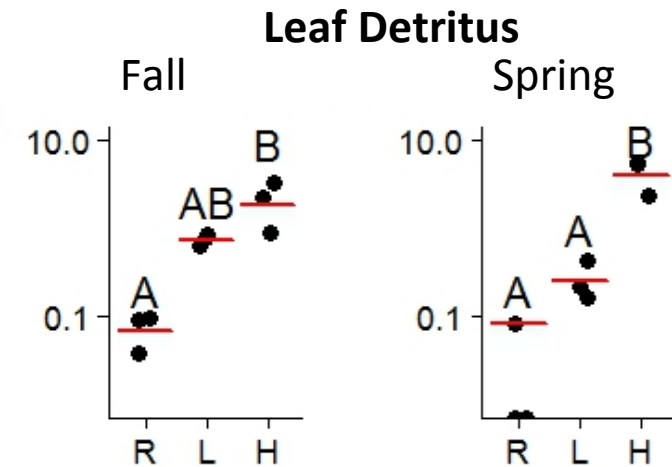
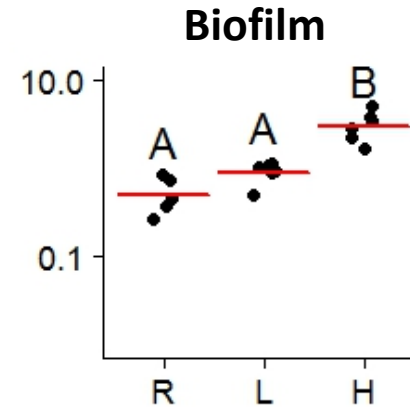
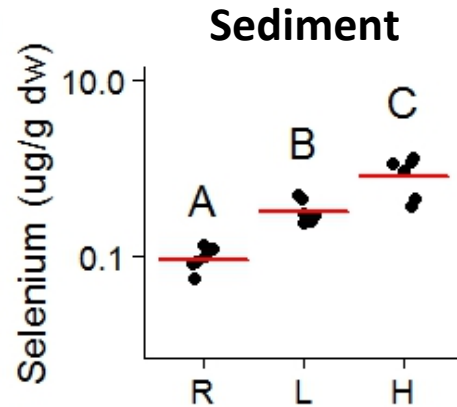
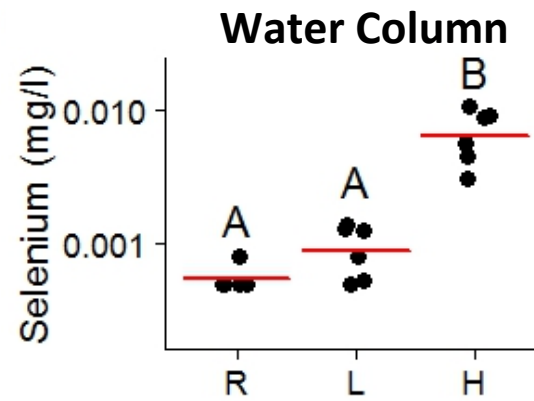
Phase II: Results

- Differences between sampling seasons were minimal
- Consistent pattern of elevated Se concentrations in streams influenced by coal mining



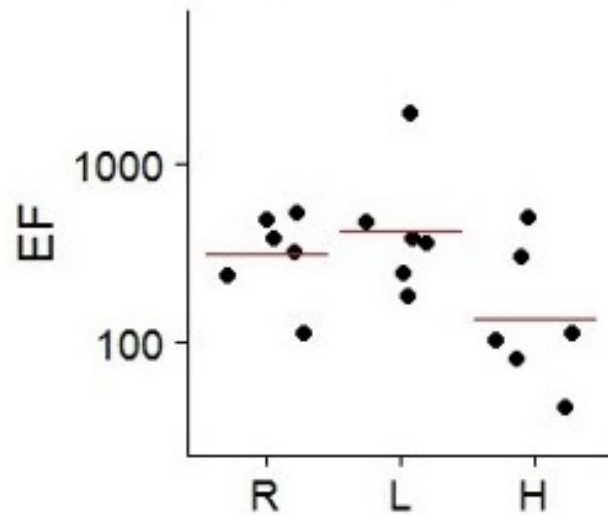
Phase II: Results

- Differences between sampling seasons were minimal
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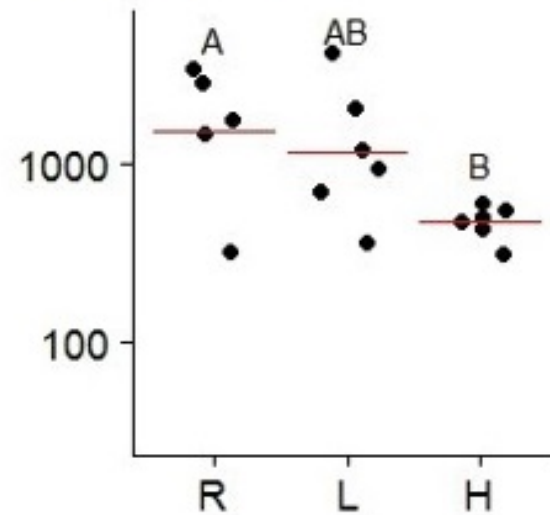


Phase II: Results – Enrichment Factors

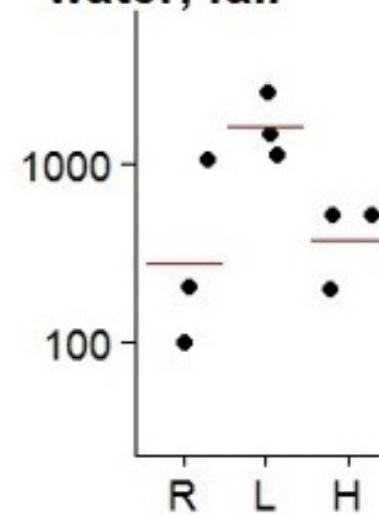
A sediment : water



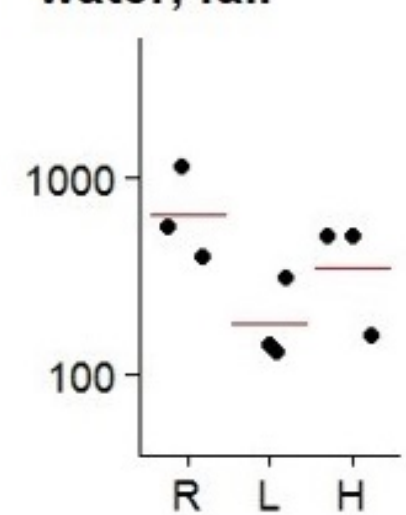
B biofilm : water



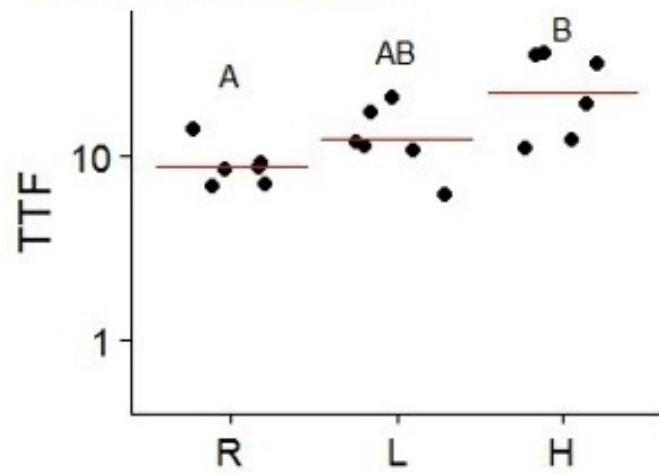
C leaf detritus: water, fall



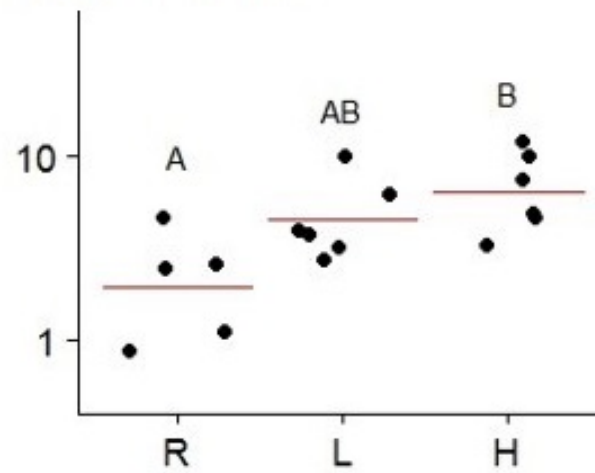
D leaf detritus: water, fall



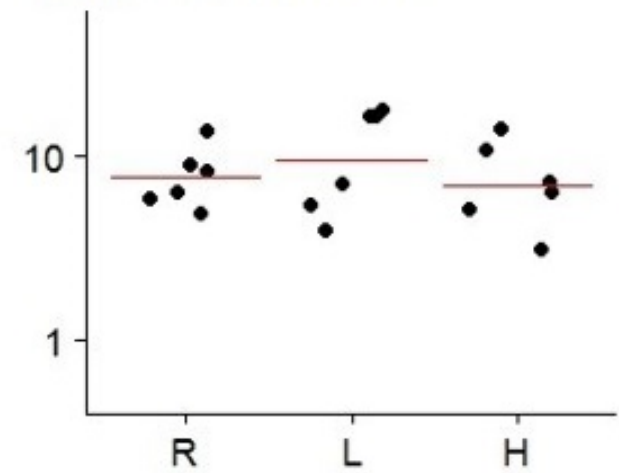
E prey : sediment



F prey : biofilm



G prey : leaf detritus



H predator : prey

