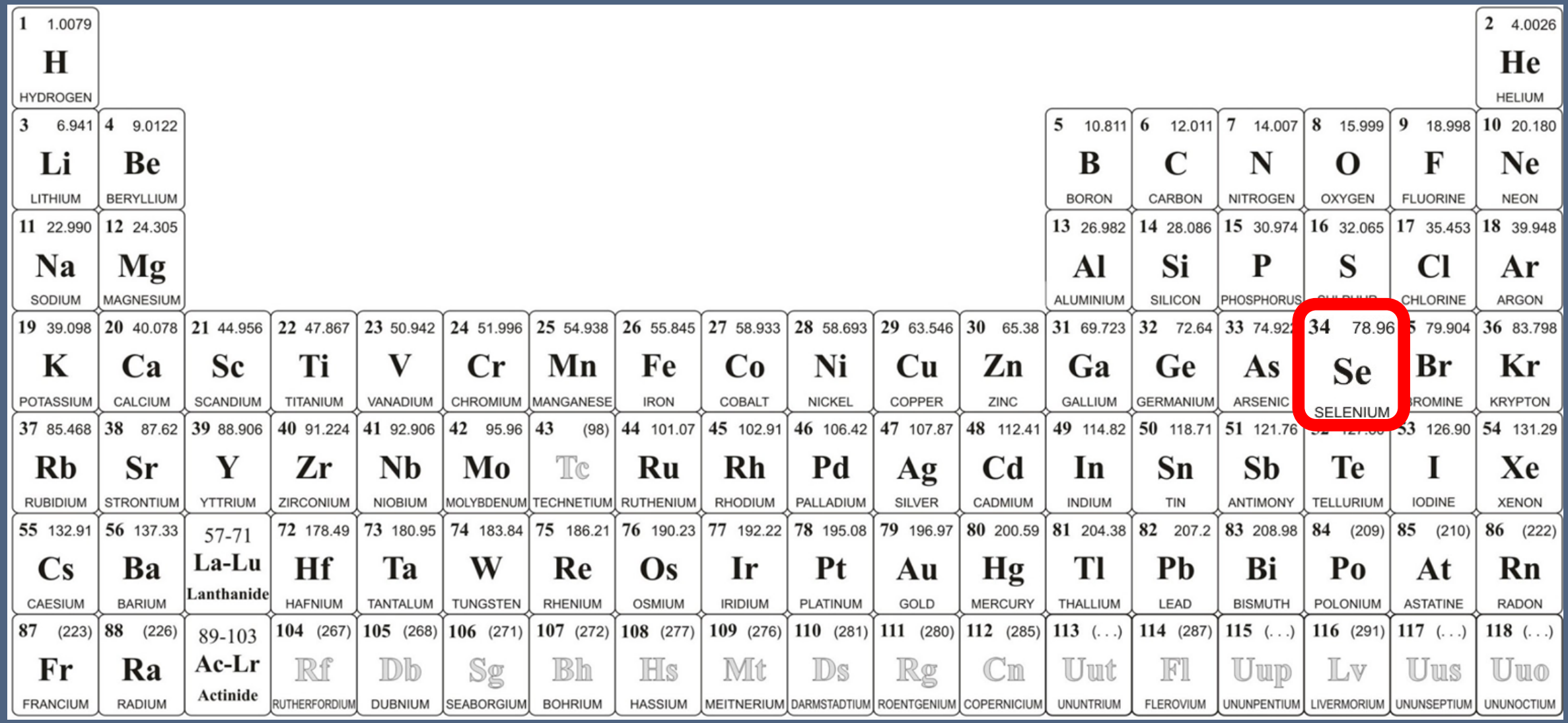
Selenium Dynamics in Mining-Influenced Headwater Streams of Central Appalachia

Kriddie Whitmore

Selenium: Trace Element



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

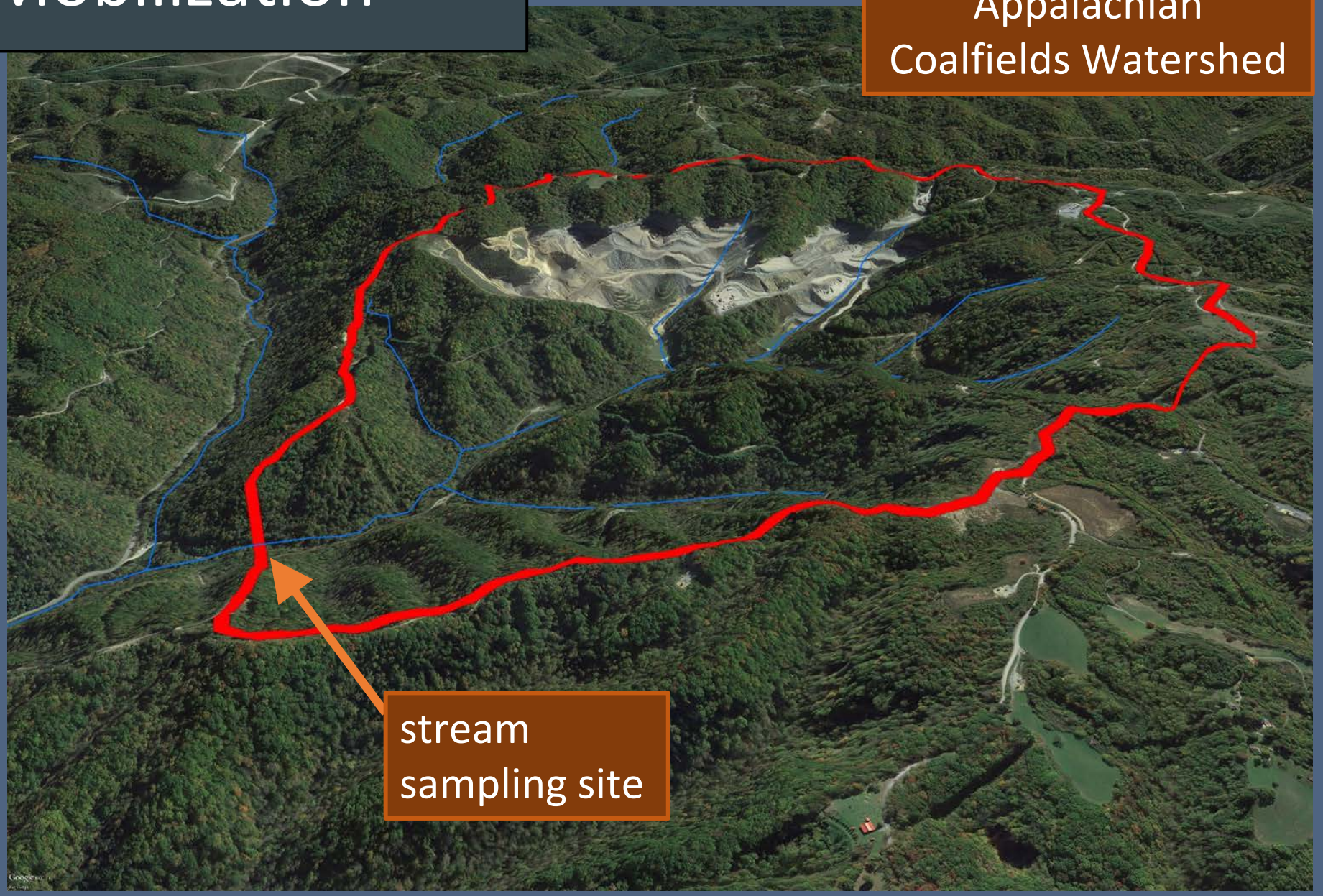
Table 4.1. Summary of the Recommended Freshwater Selenium Ambient Chronic Water Quality Criterion for Protection of Aquatic Life.

Media Type	Fish Tissue[1]		Water Column[4]	
Criterion Element	**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 or 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

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



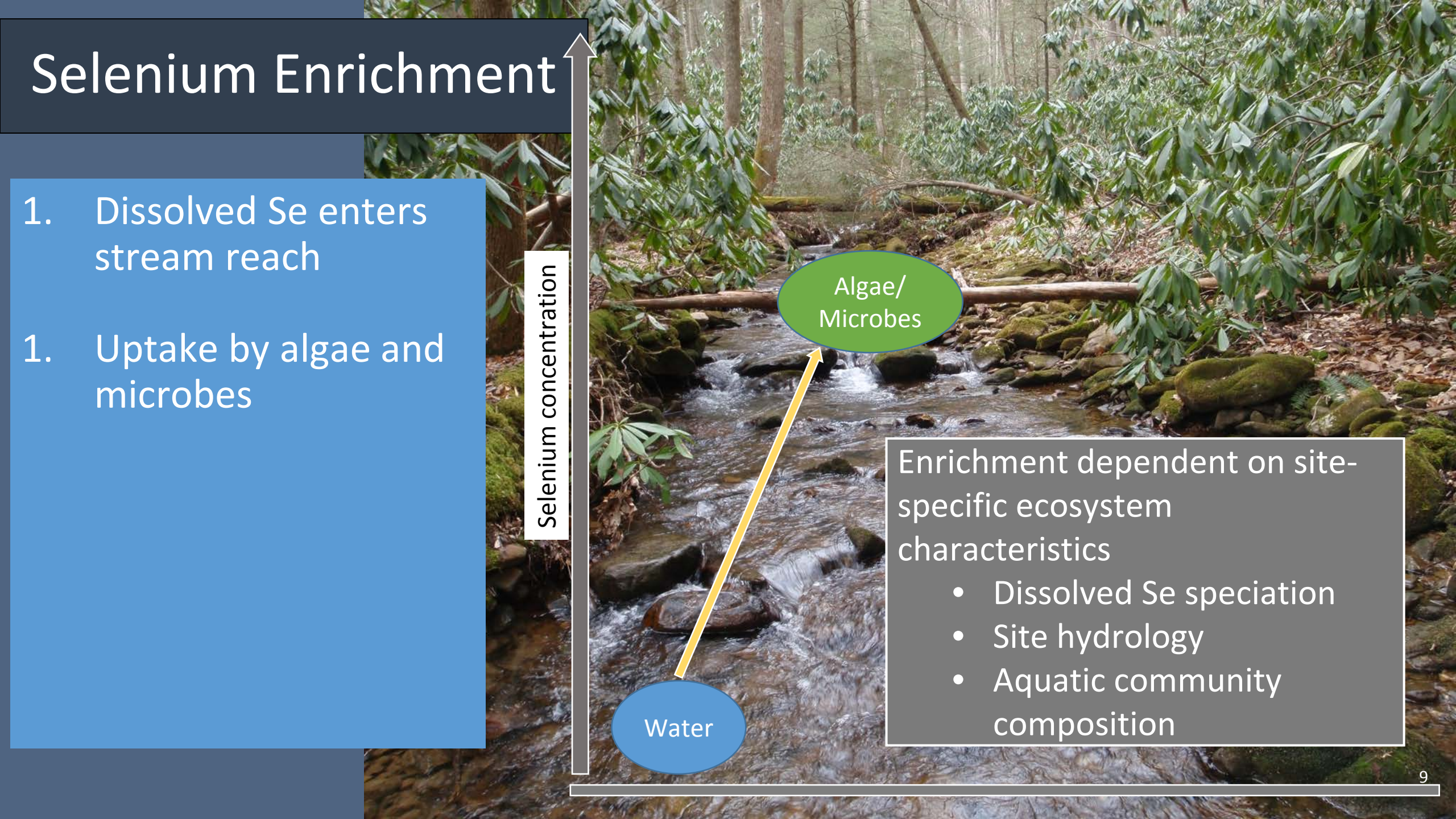
Selenium Enrichment

1. Dissolved Se enters stream reach

Selenium Enrichment

1. Dissolved Se enters stream reach

1. Uptake by algae and microbes

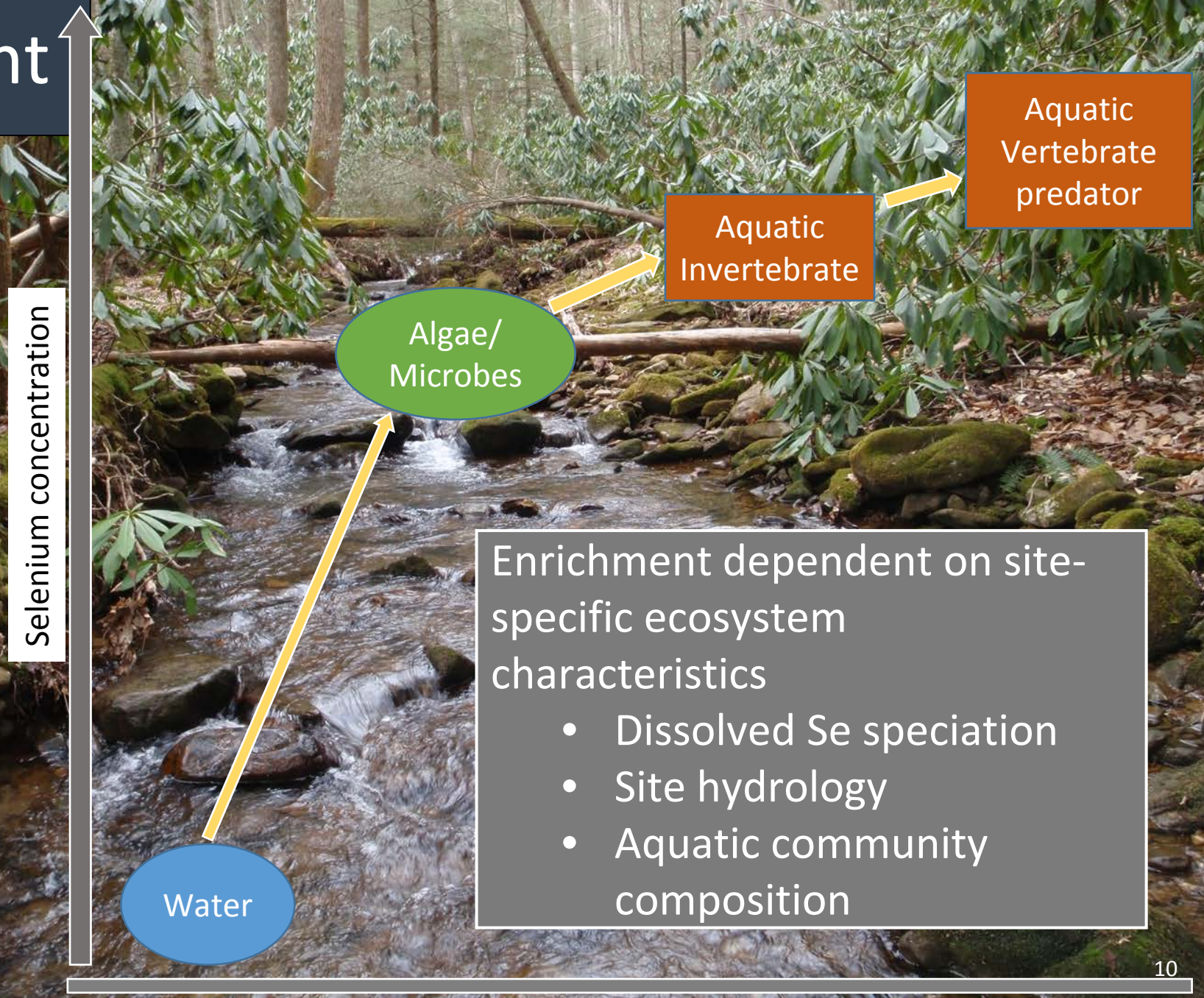


Enrichment dependent on site-specific ecosystem characteristics

- 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



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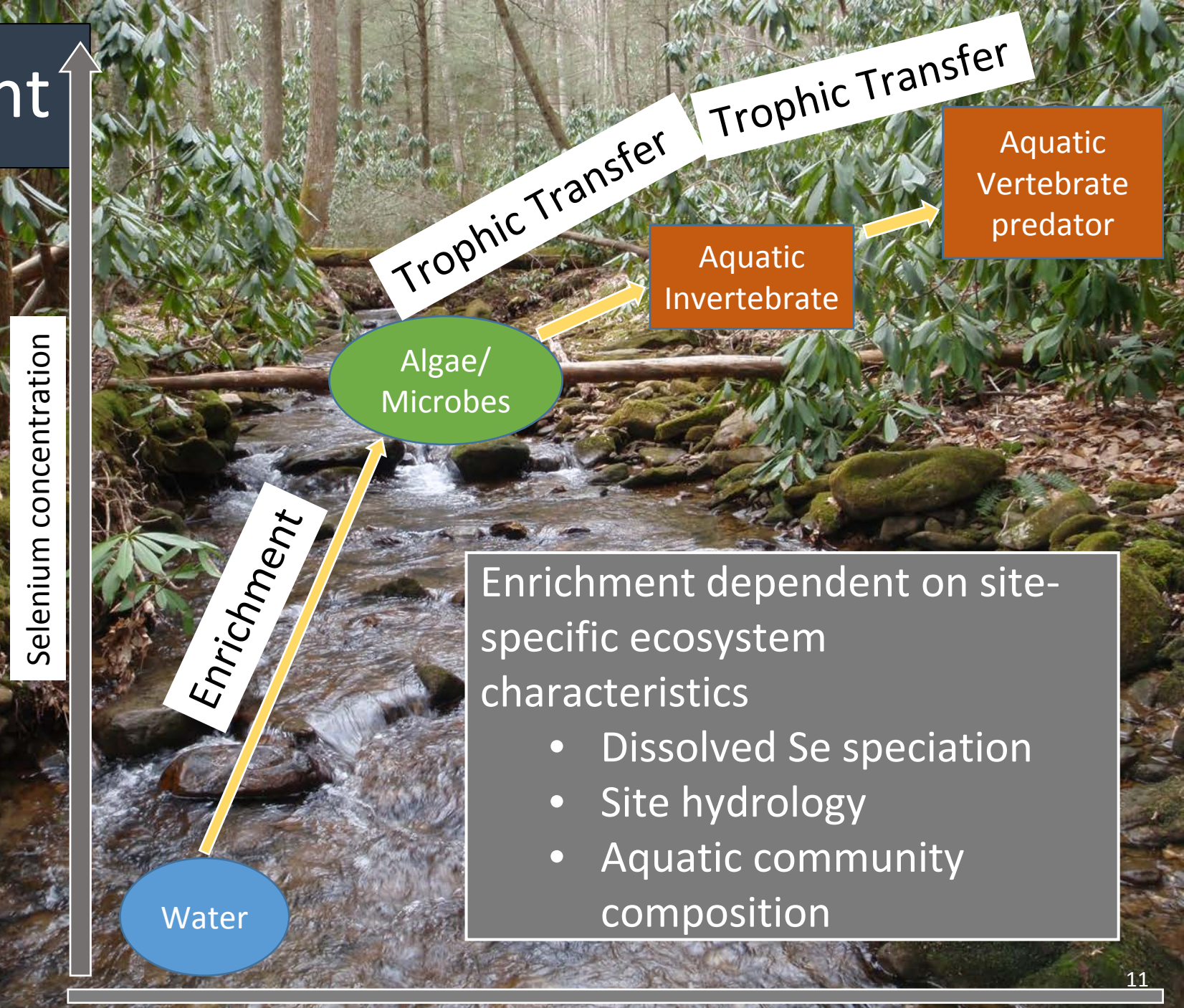


Enrichment dependent on site-specific ecosystem characteristics

- Dissolved Se speciation
- Site hydrology
- Aquatic community composition

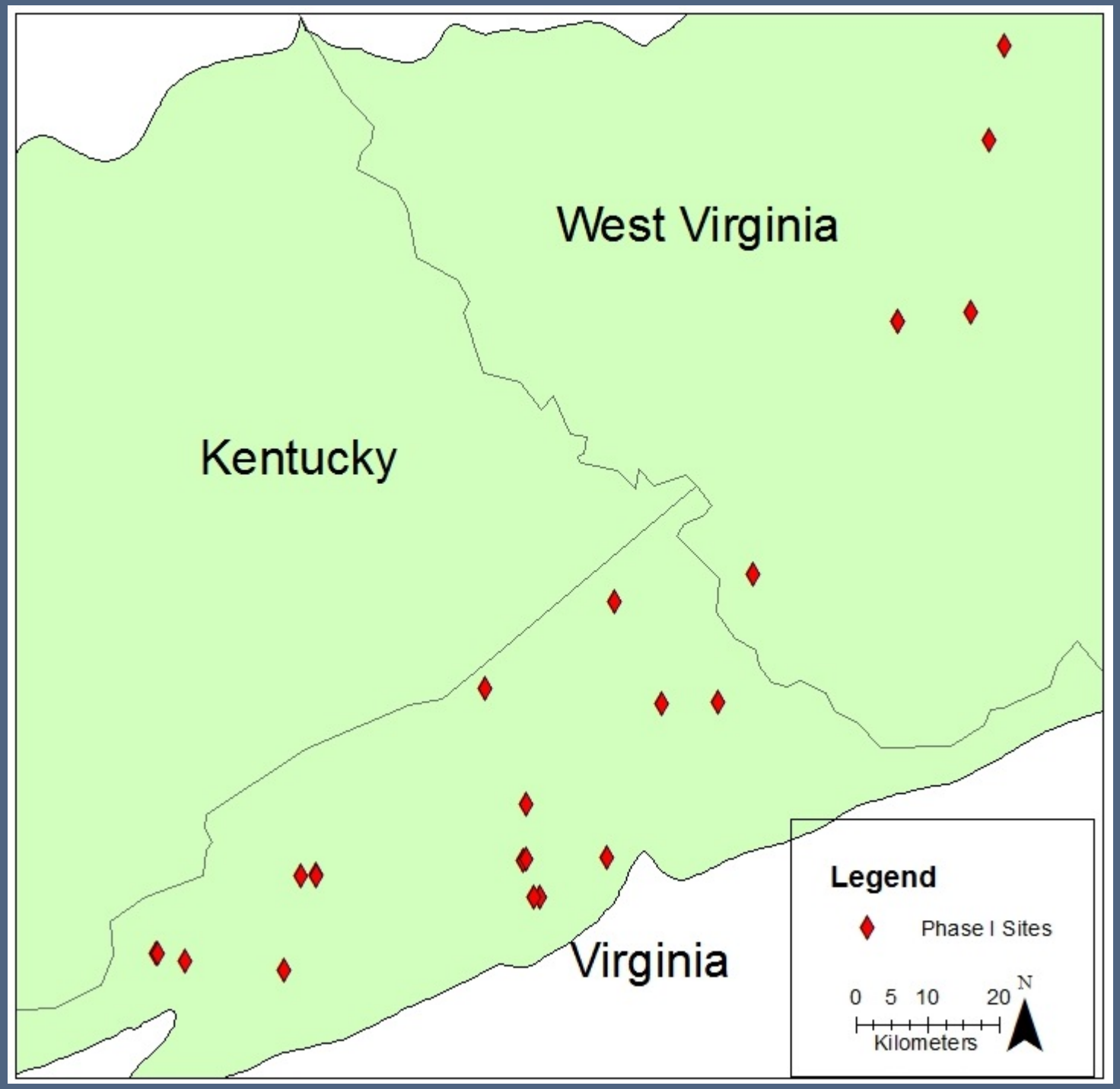
Research Questions

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?

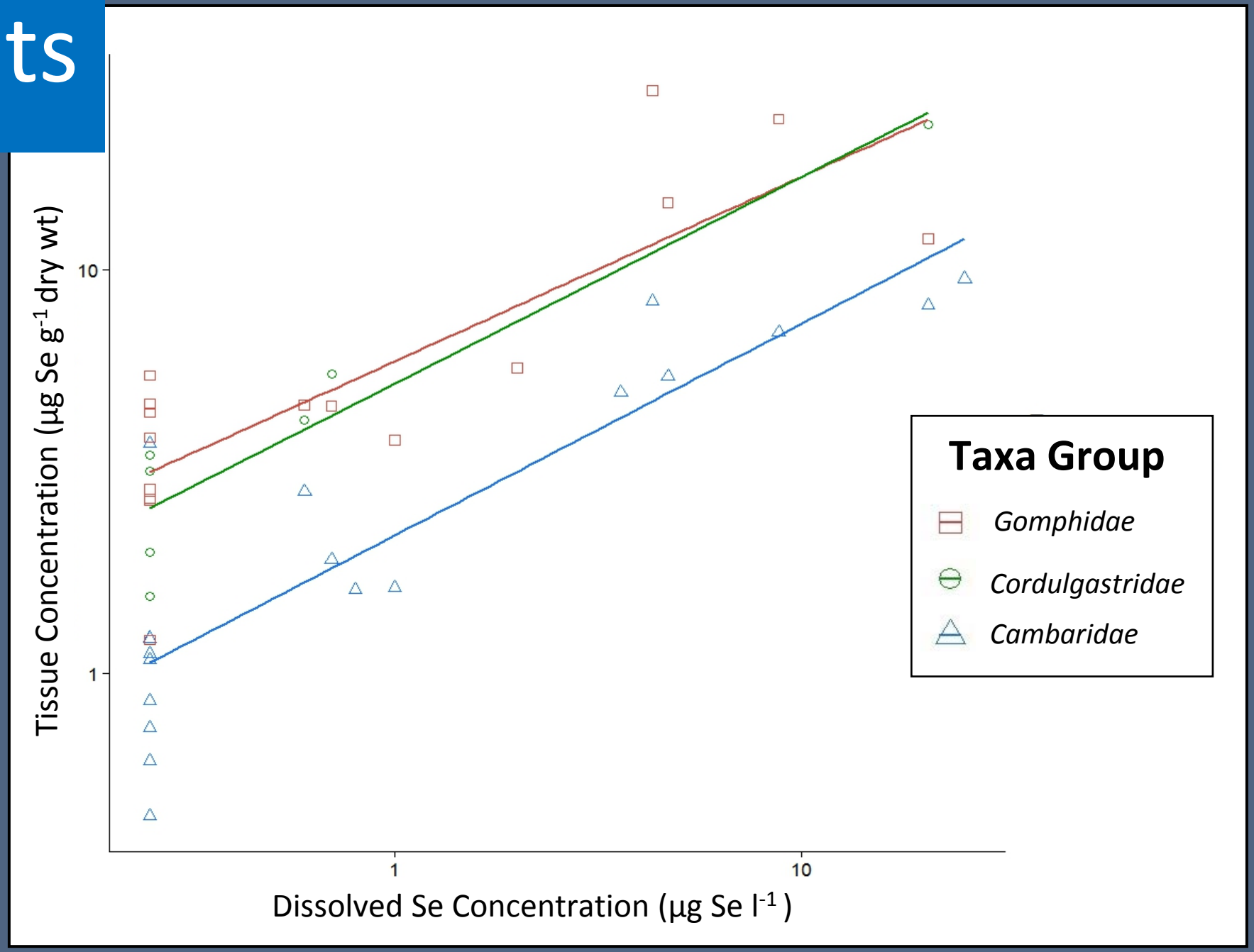


Phase I Methods

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

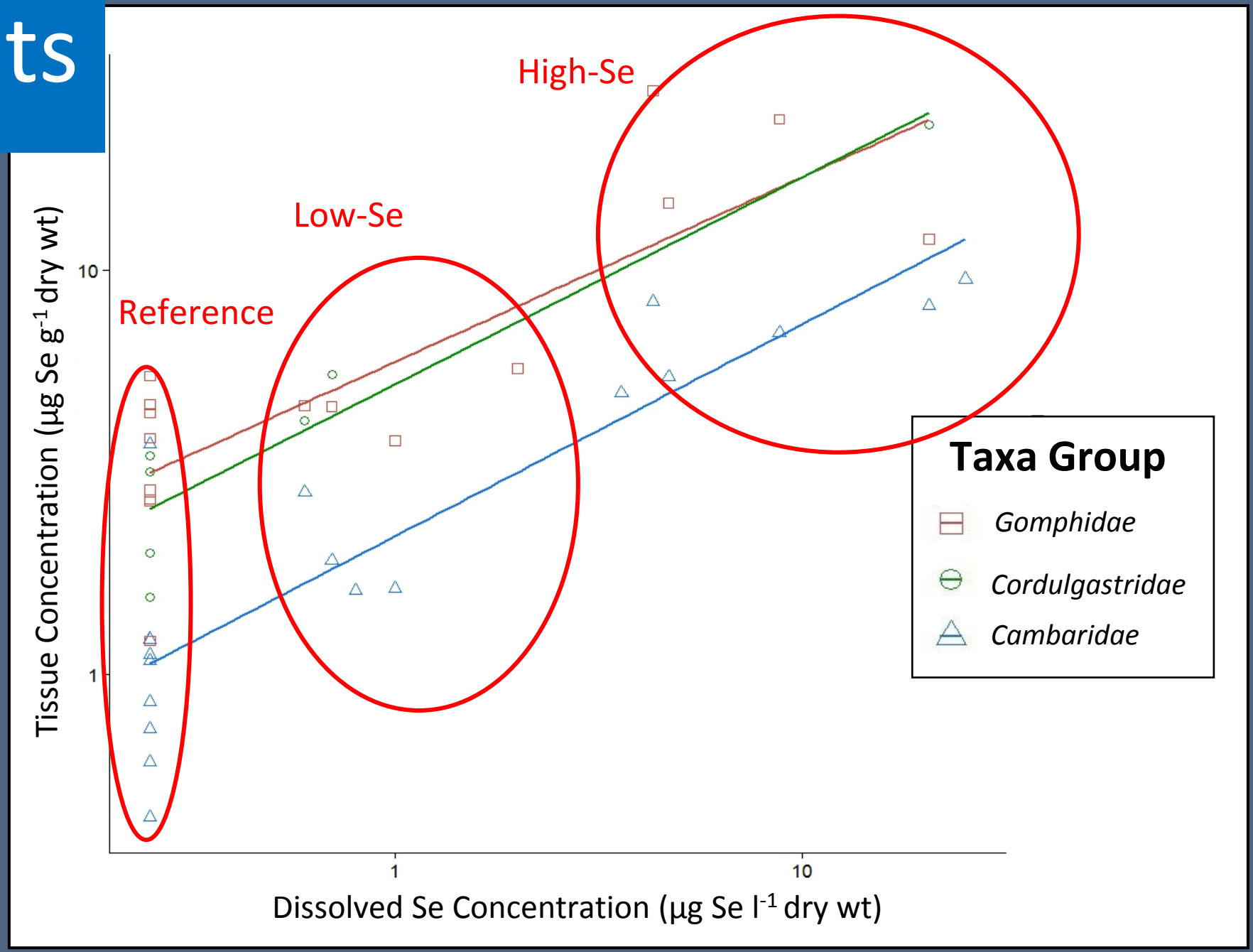
Phase I Results

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



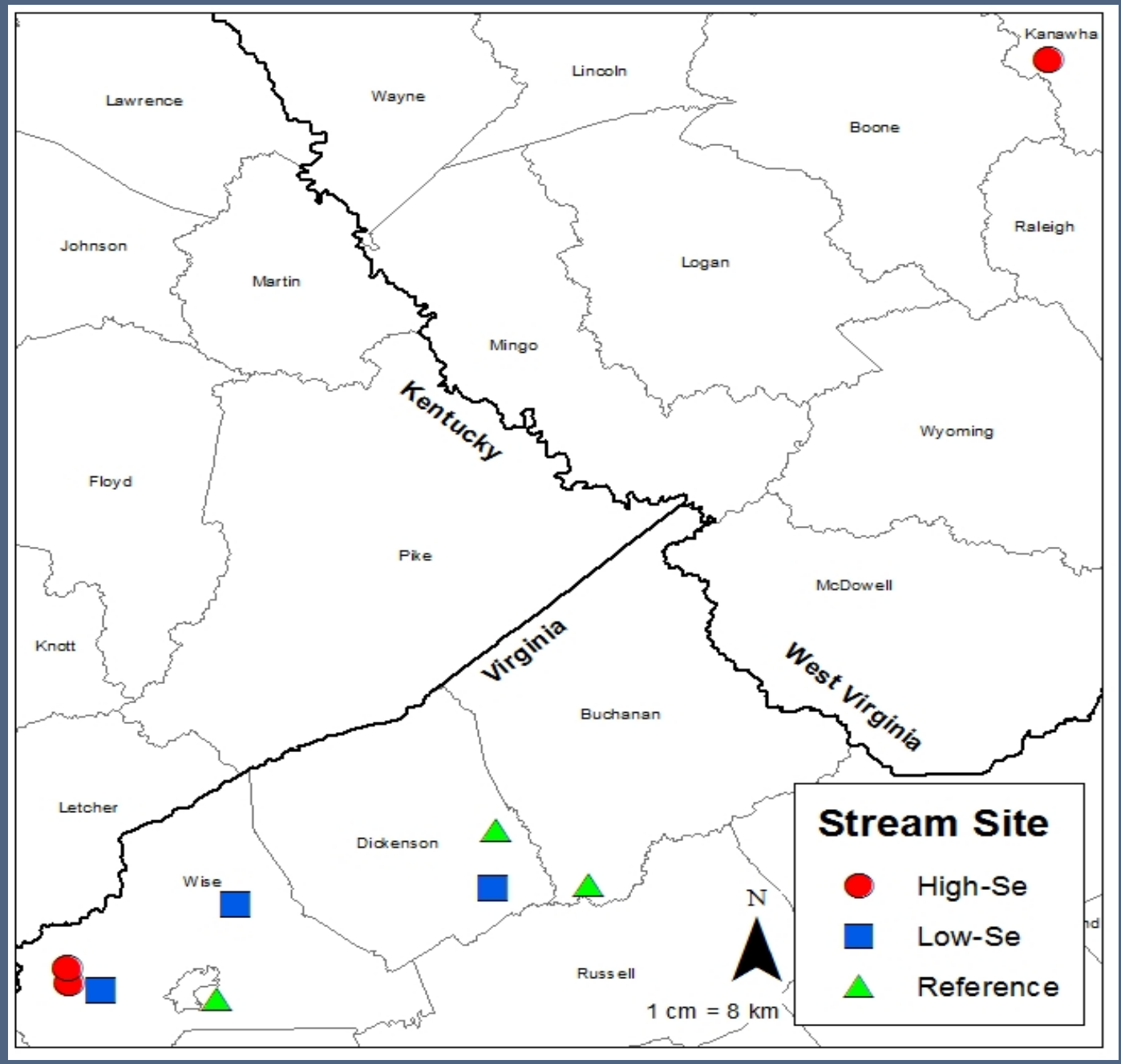
Phase I Results

- Site selection



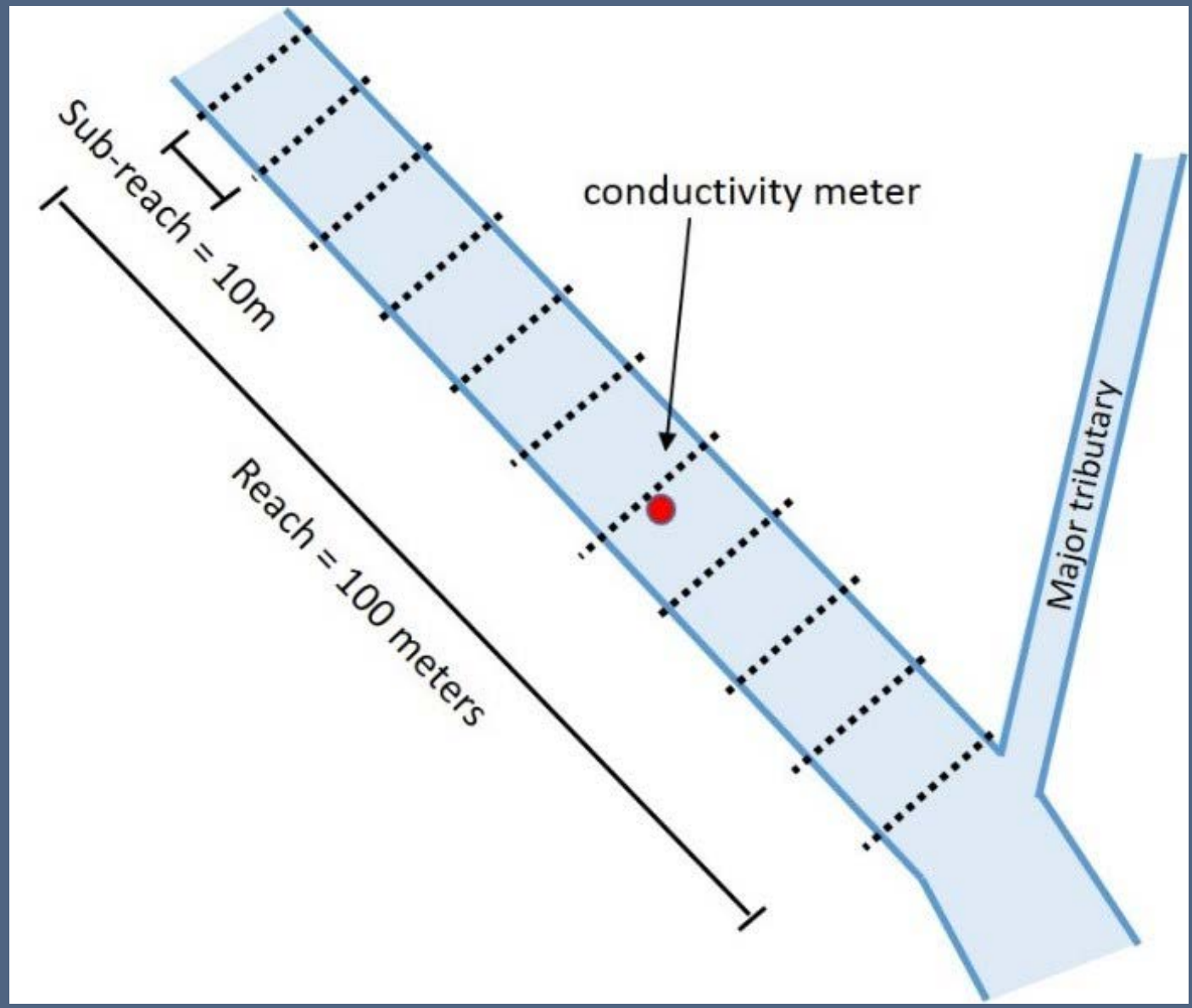
Phase II

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

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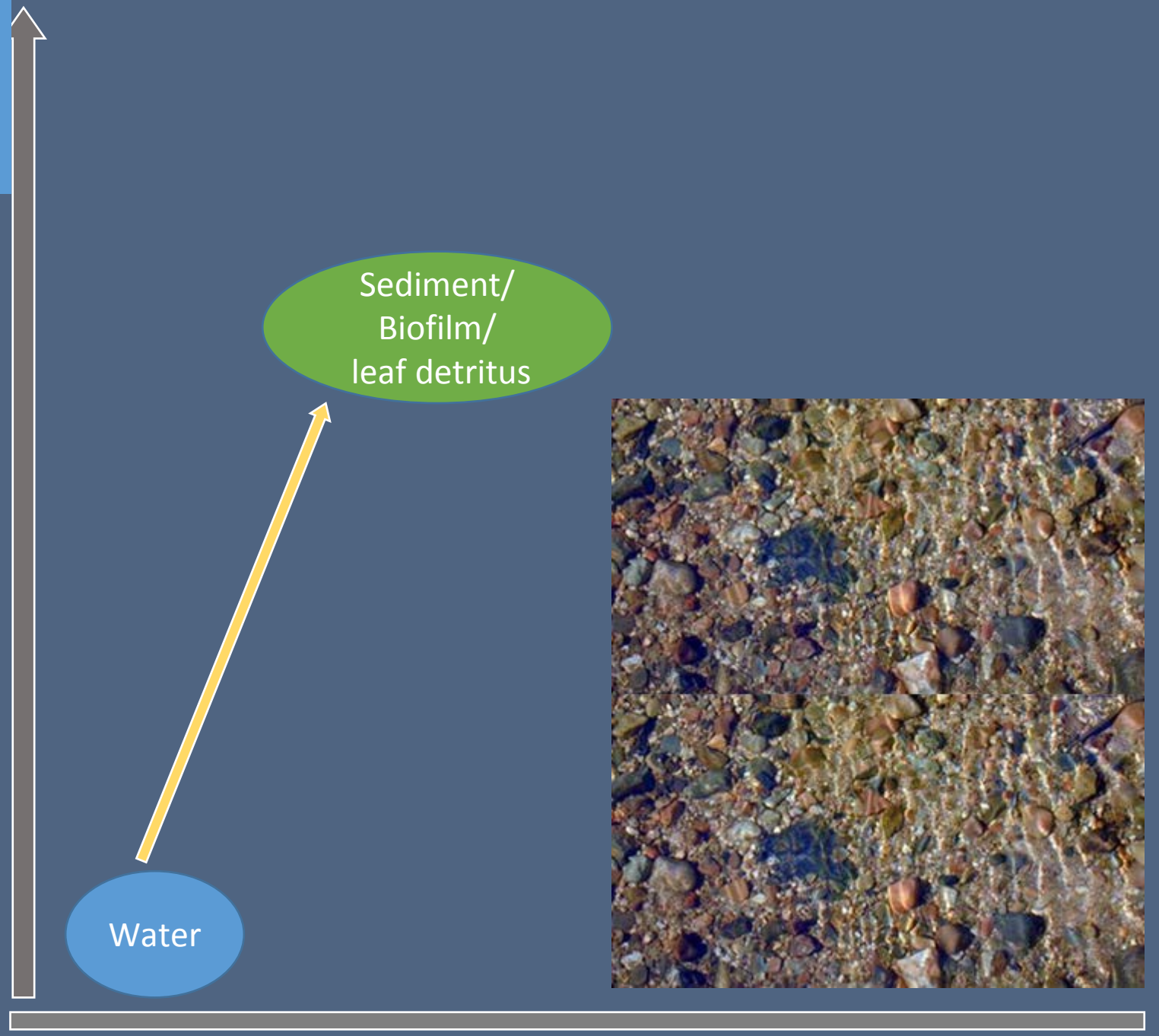
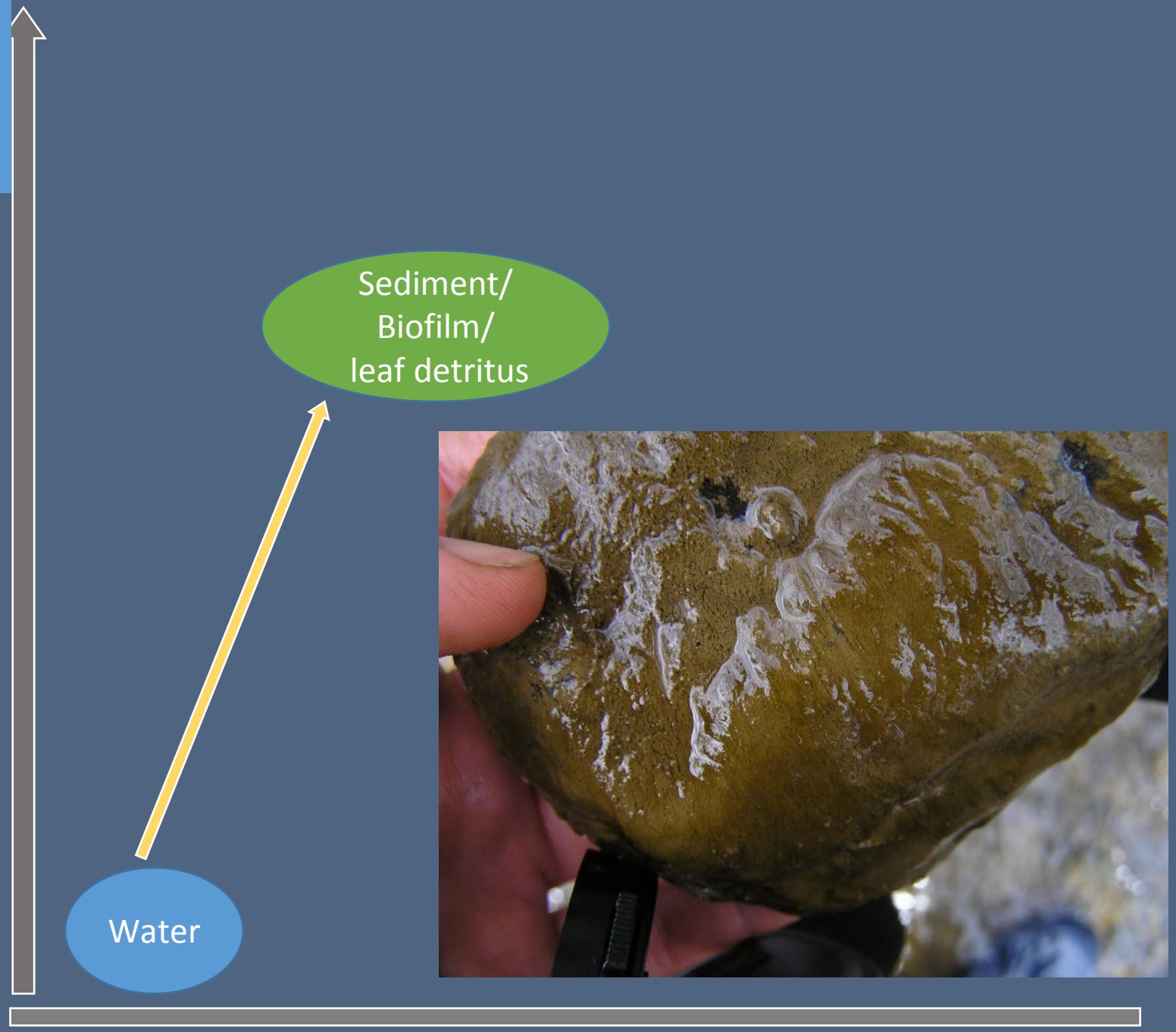
- Media Collected
  - Water-column
  - Sediment



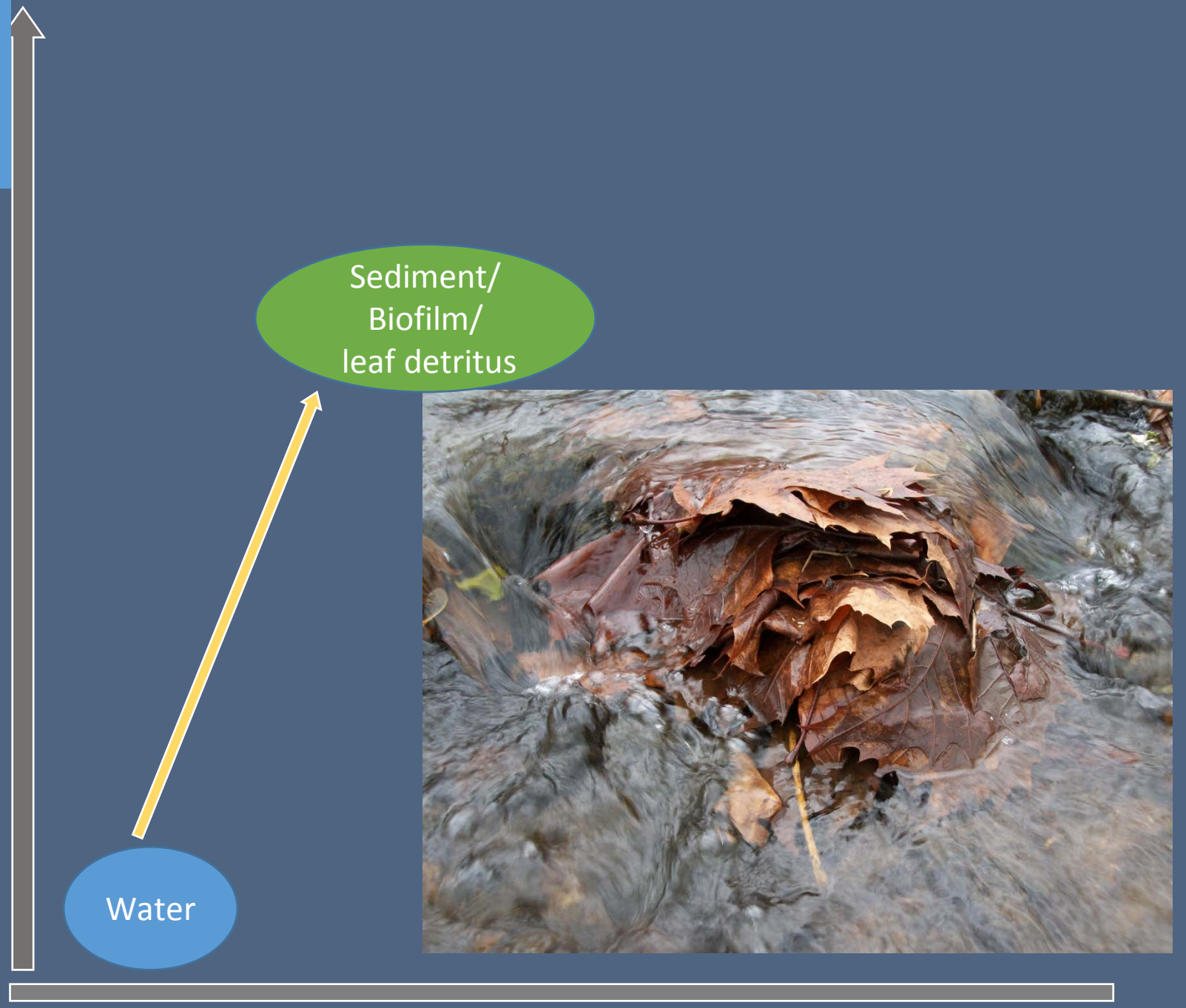
Phase II Methods

- Media Collected
  - Water-column
  - Sediment
  - Biofilm



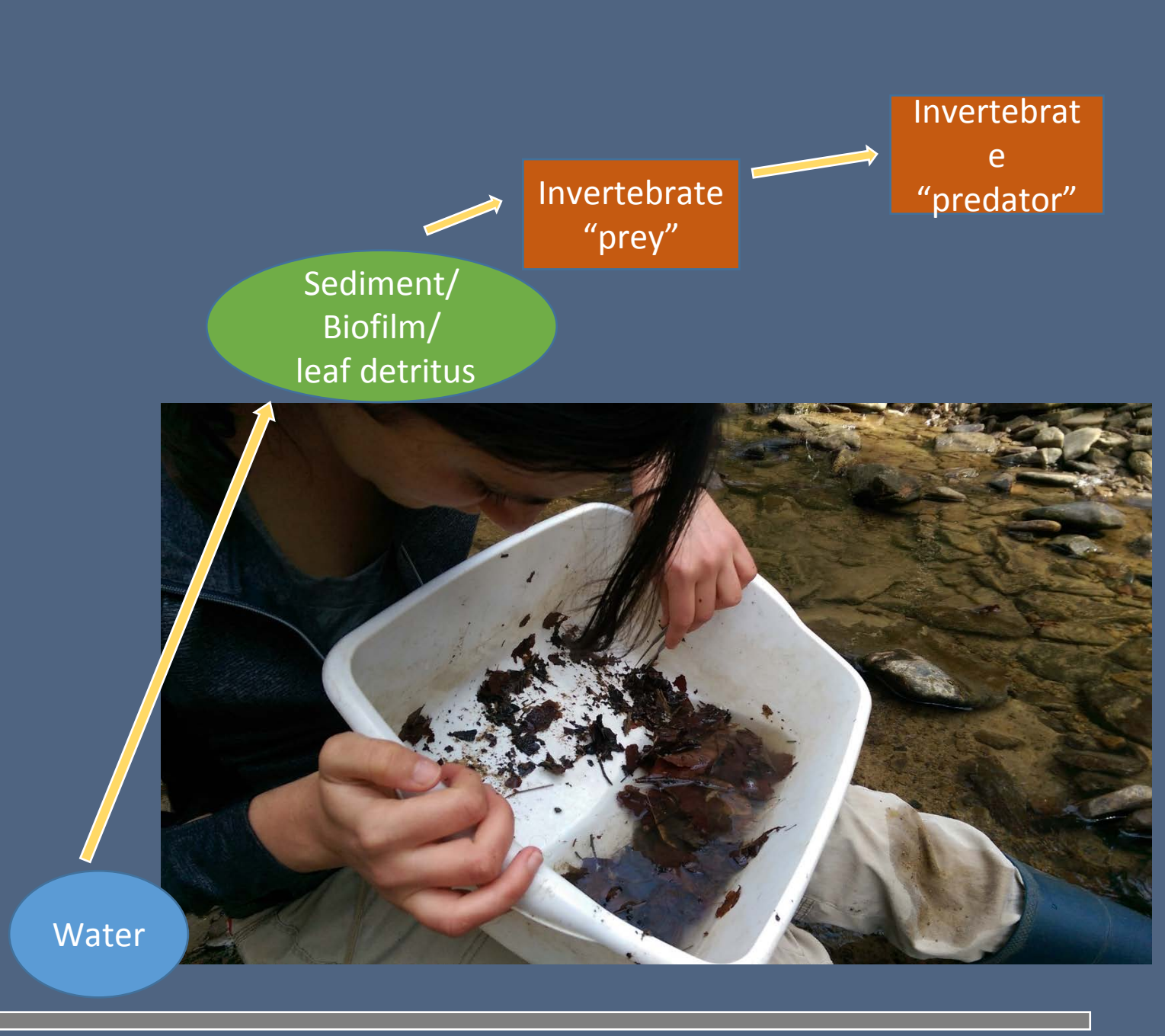
Phase II Methods

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



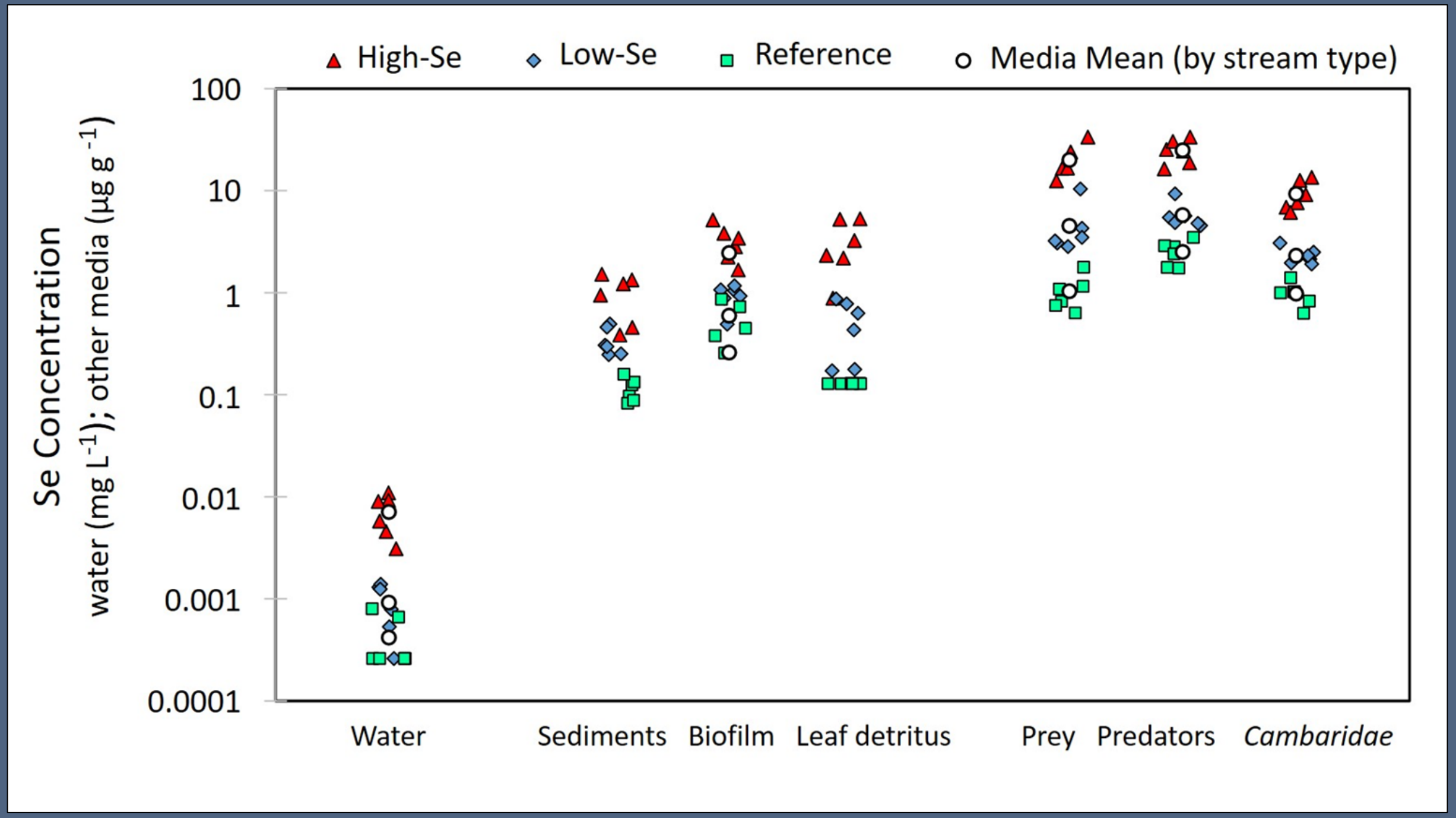
Phase II Methods

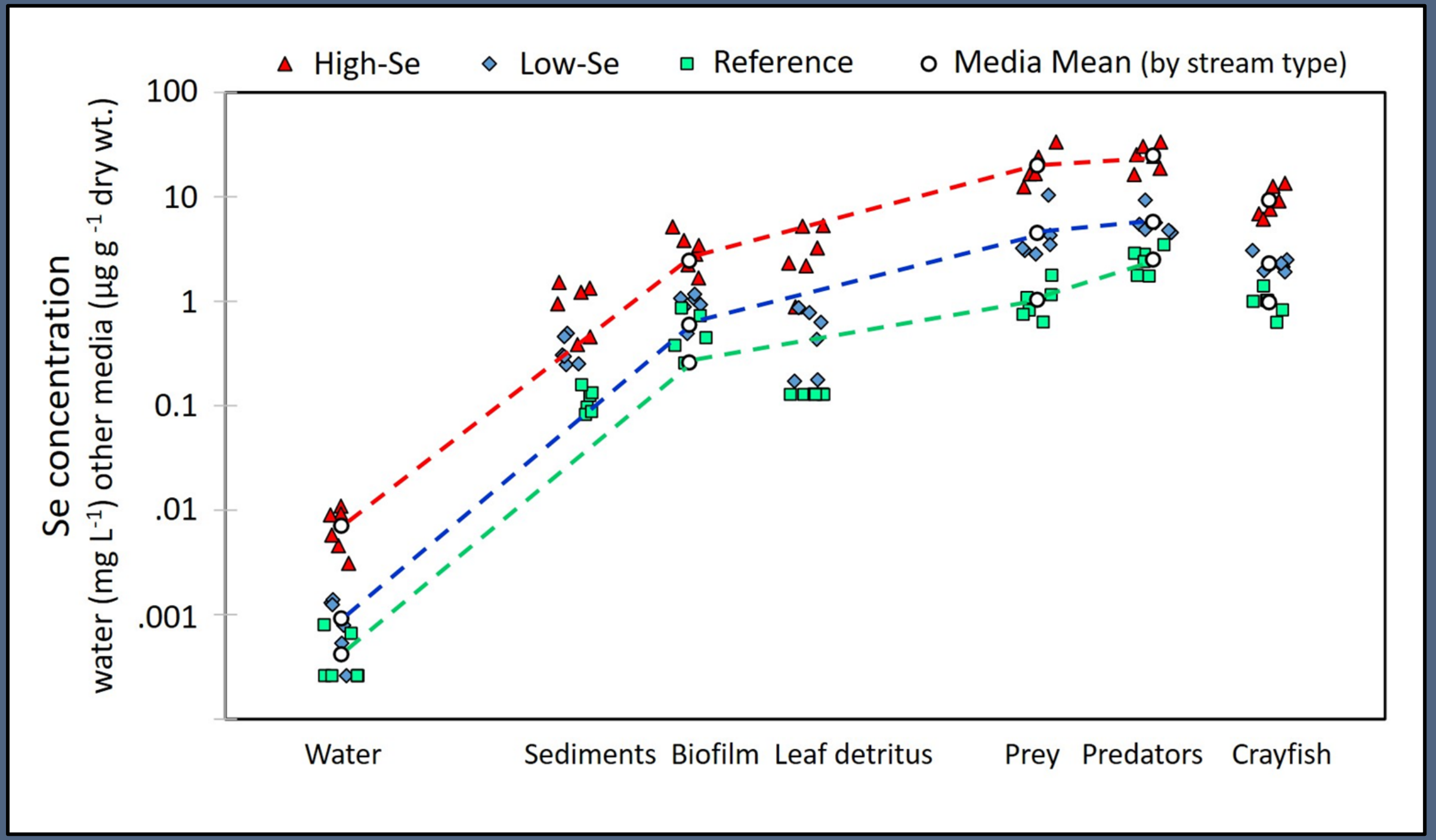
- Media Collected
  - Water-column
  - Sediment
  - Biofilm
  - Leaf detritus
  - Macroinvertebrates
  - Crayfish



Phase II Methods

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


High-Se
Low-Se
Reference
Media Mean (by stream type)
Se Concentration
water (mg L-1); other media (µg g-1)
100
10
1
0.1
0.01
0.001
0.0001
Water
Sediments
Biofilm
Leaf detritus
Prey
Predators
Cambaridae


High-Se
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water (mg L-1) other media (µg g -1 dry wt.)
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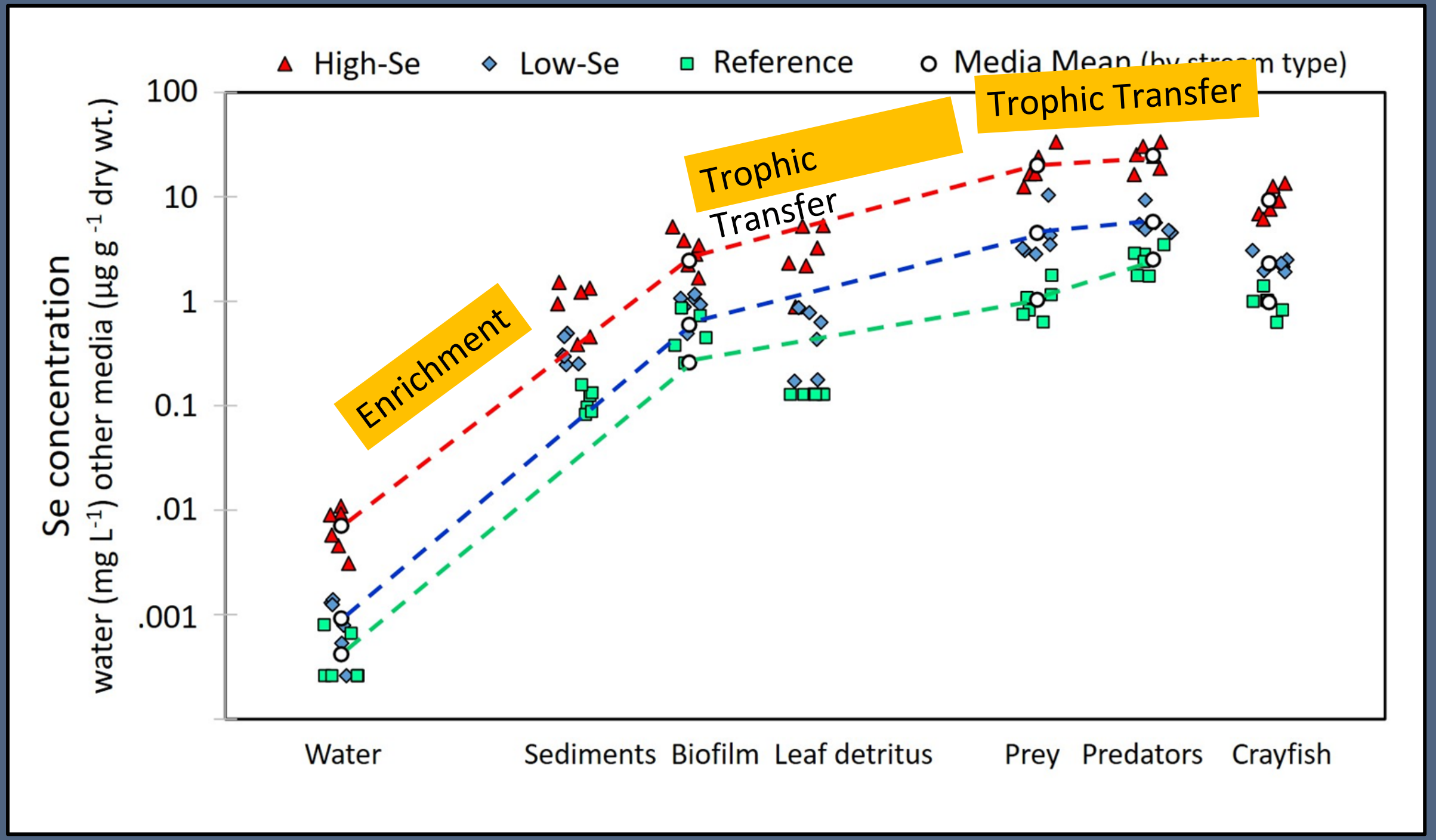
High-Se
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Media Mean (by stream type)
Se concentration
water (mg L-1) other media (µg g-1 dry wt.)
100
10
1
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.01
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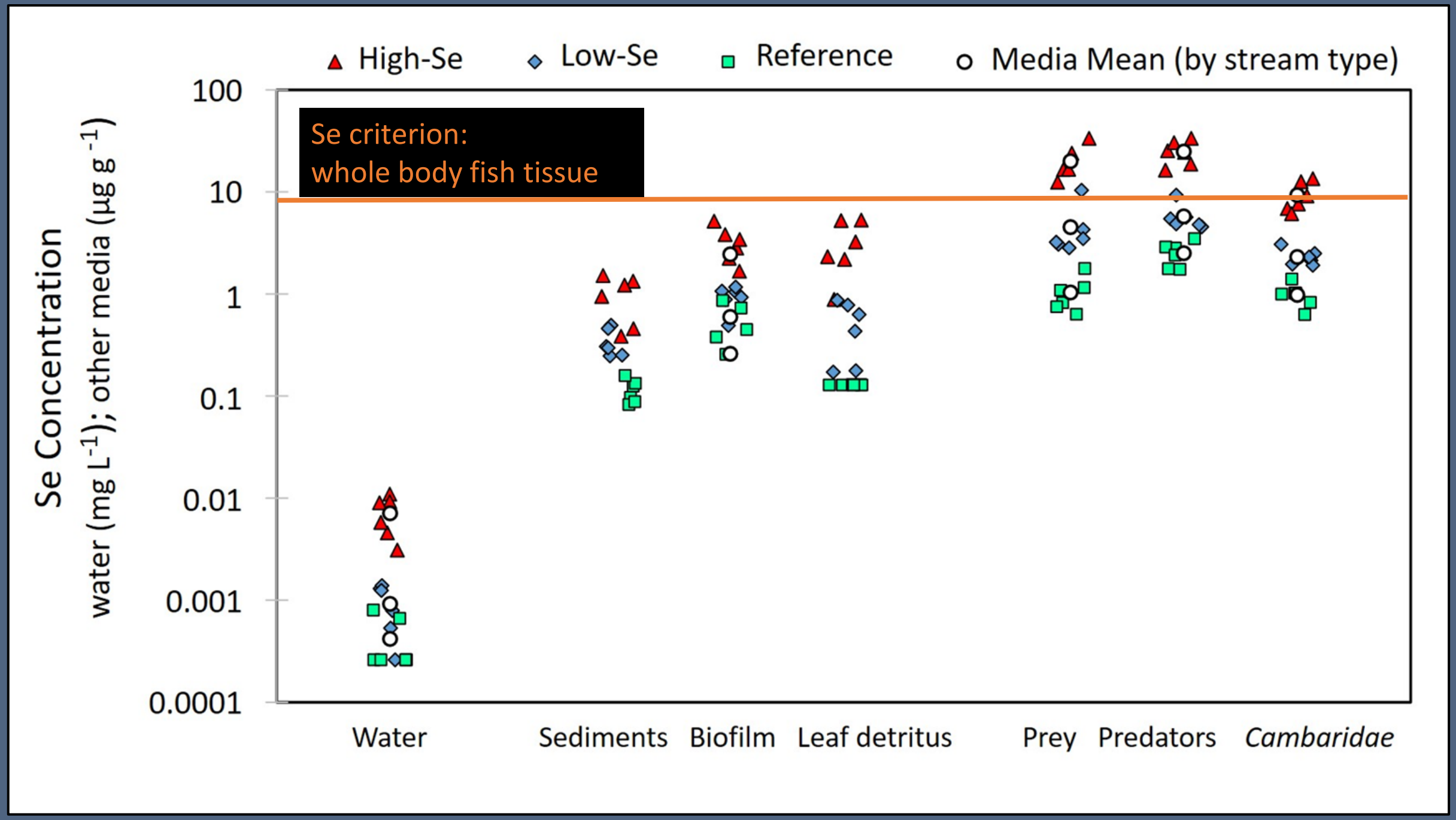
Enrichment
Trophic Transfer
Trophic Transfer
Water
Sediments
Biofilm
Leaf detritus
Prey
Predators
Crayfish


High-Se
Low-Se
Reference
Media Mean (by stream type)
Se criterion:
whole body fish tissue
Se Concentration
water (mg L-1); other media (µg g-1)
100
10
1
0.1
0.01
0.001
0.0001
Water
Sediments
Biofilm
Leaf detritus
Prey
Predators
Cambaridae

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

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- Dave Mitchem
- Jeffery Parks
- Pat Donavan

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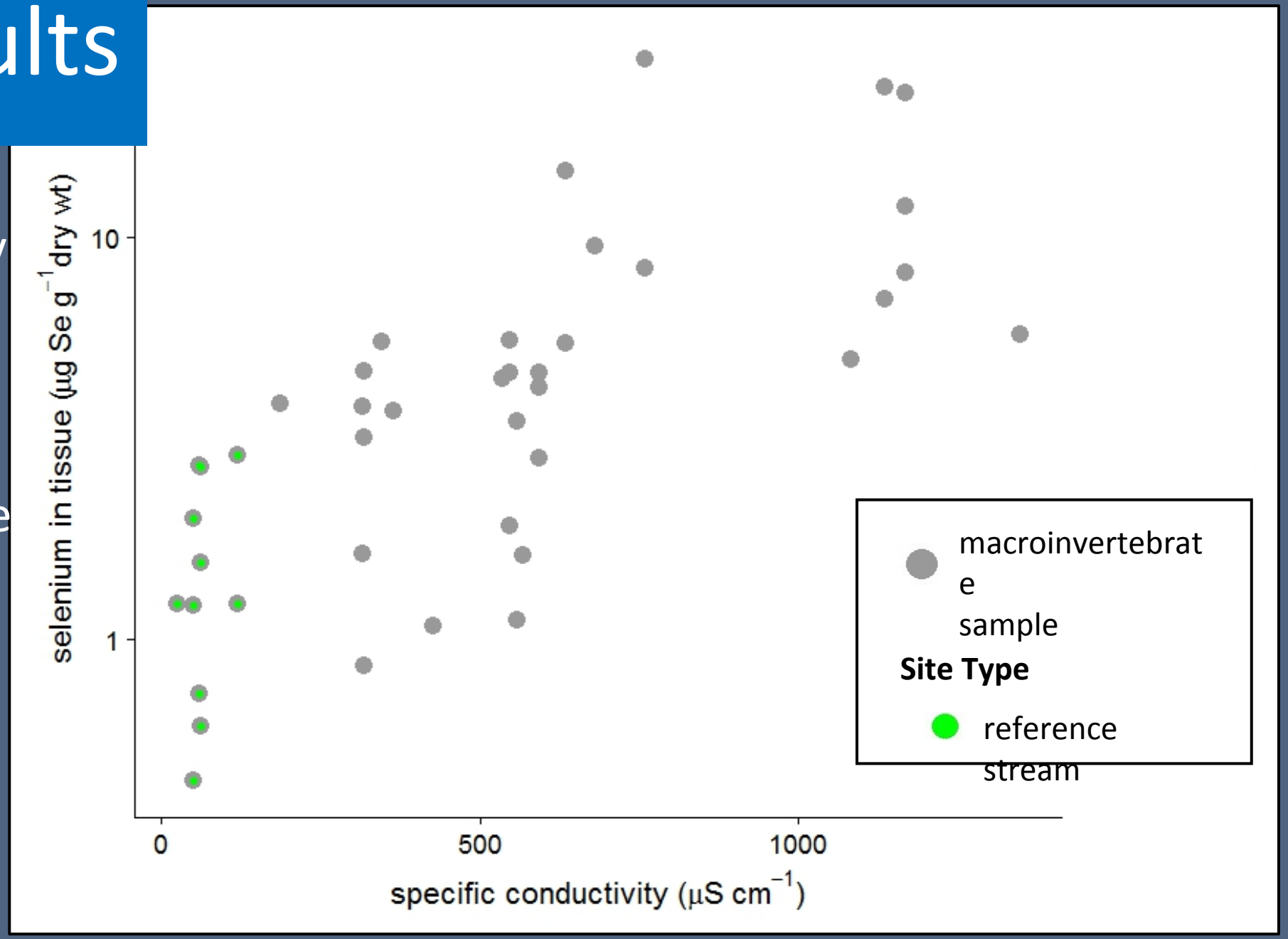
- United States Office of Surface Mining Reclamation and Enforcement

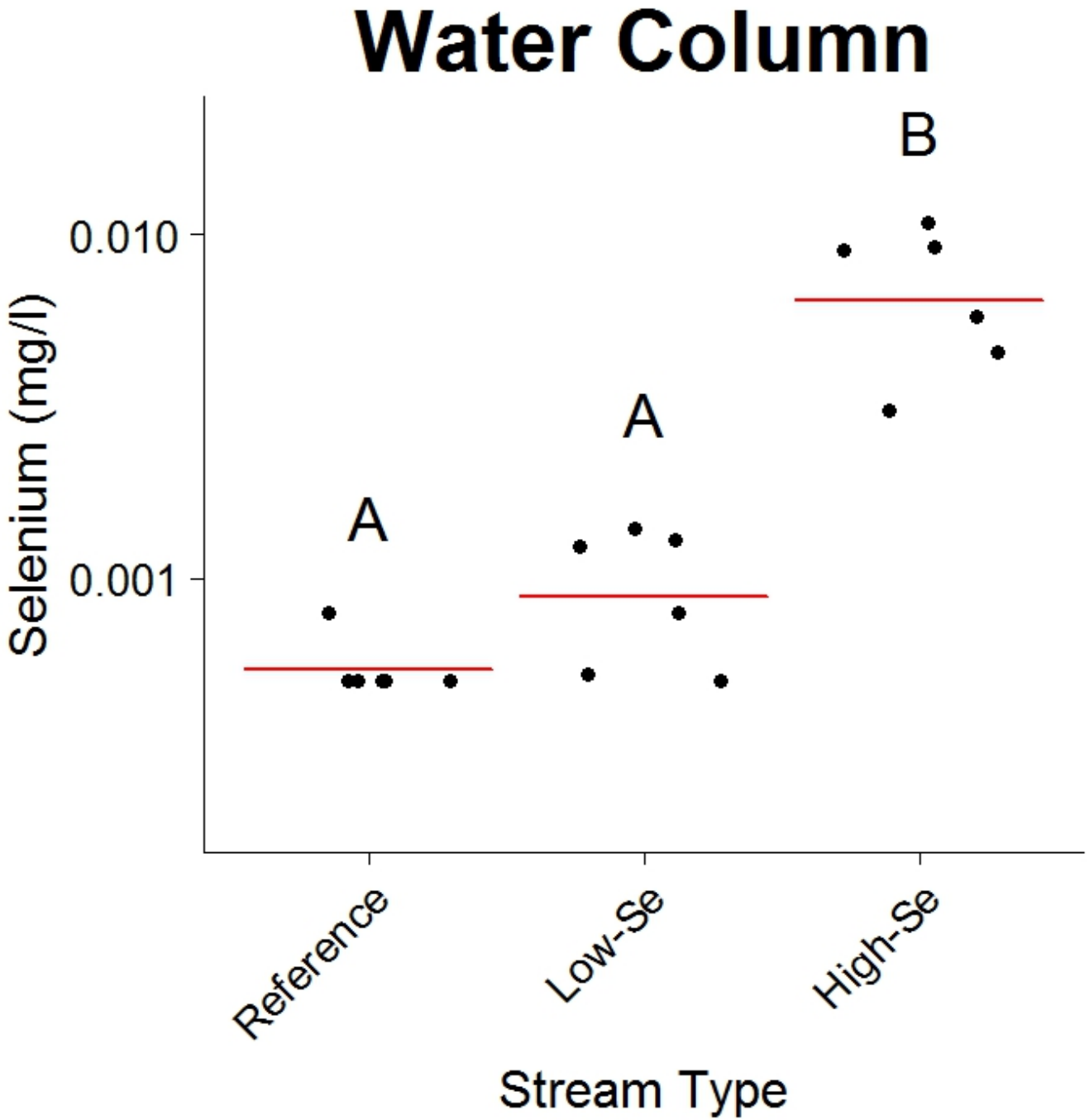
Phase I Results

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



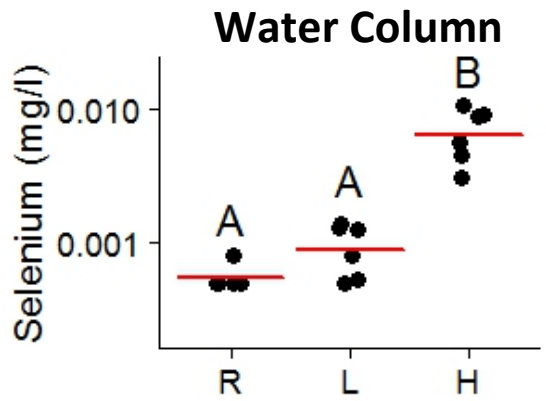
Phase II: Results

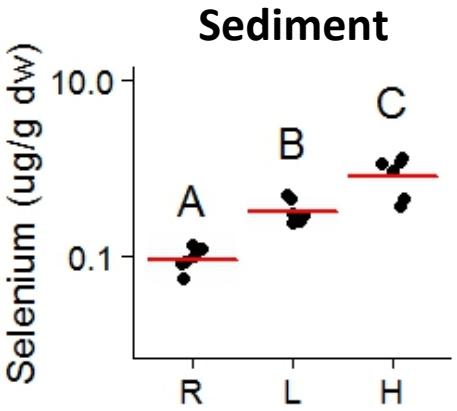
- Differences between sampling seasons were minimal
- Consistent pattern of elevated Se concentrations in streams influenced by coal mining

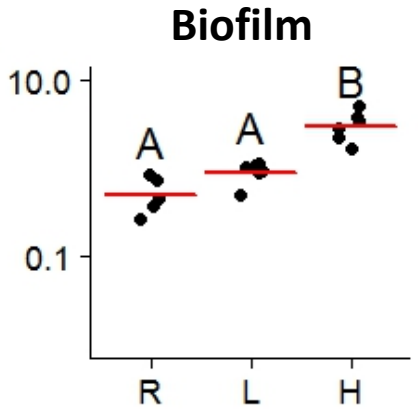


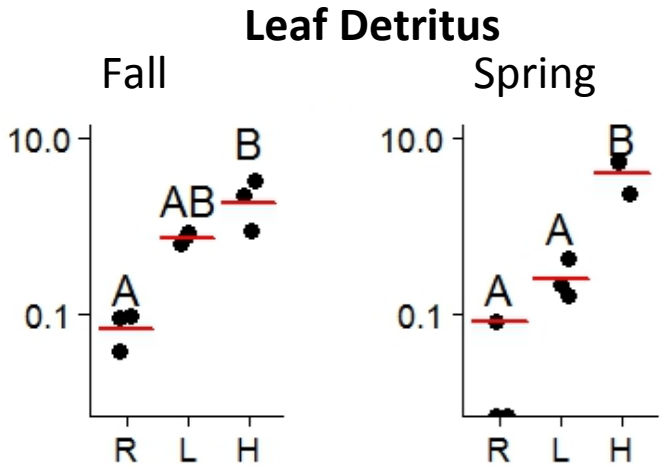
Phase II: Results

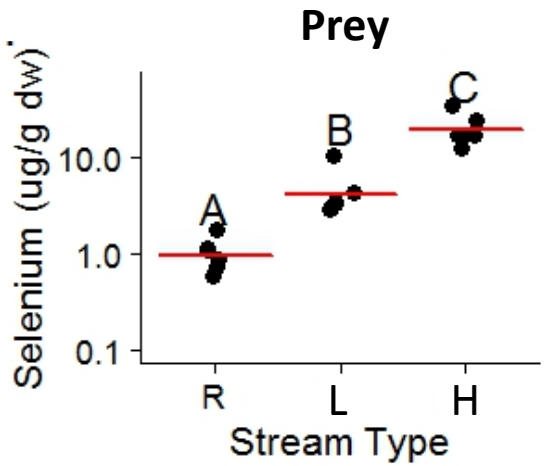
- Differences between sampling seasons were minimal
- Pattern of elevated Se concentrations in streams influenced by coal mining

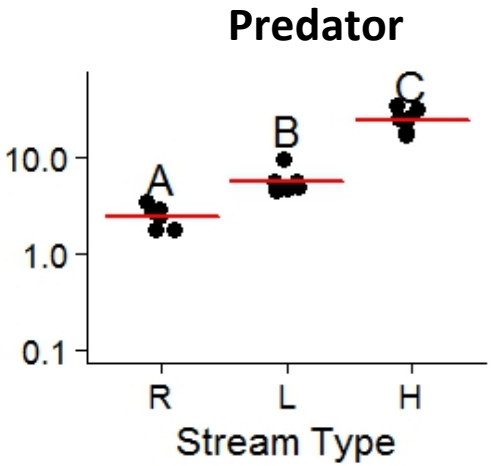


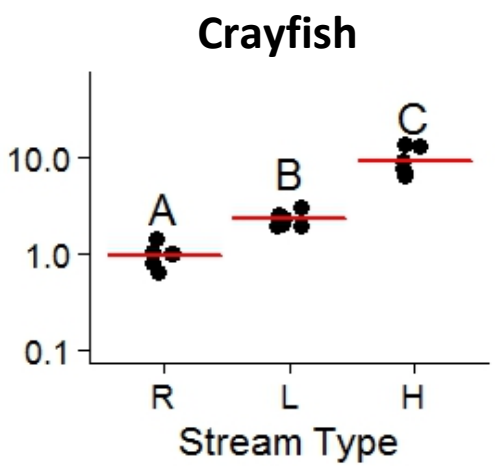




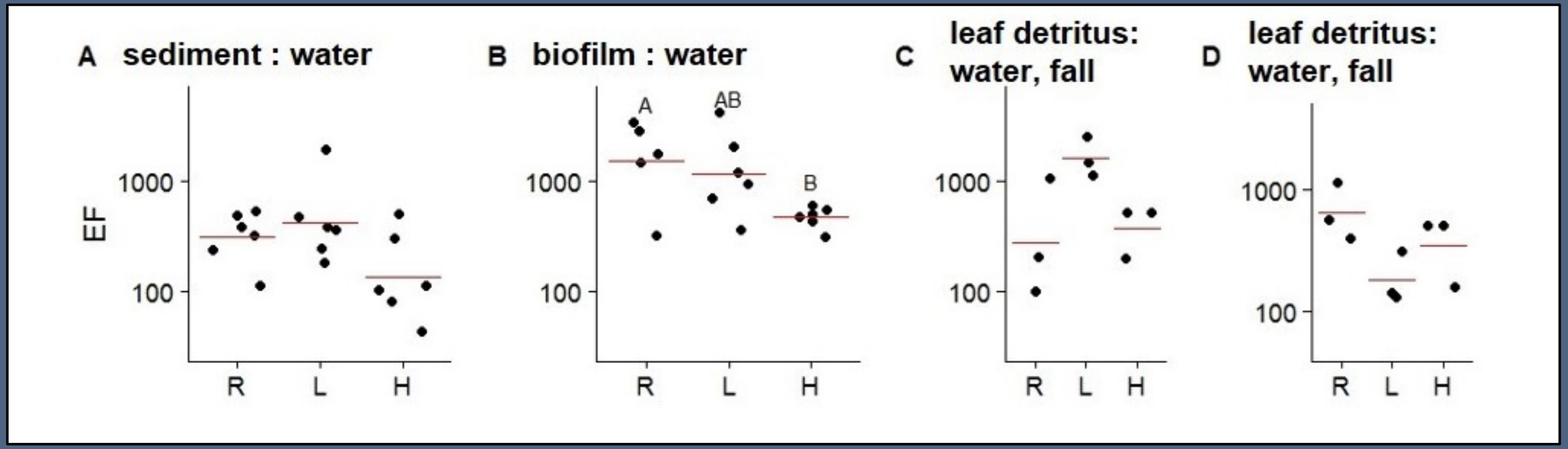


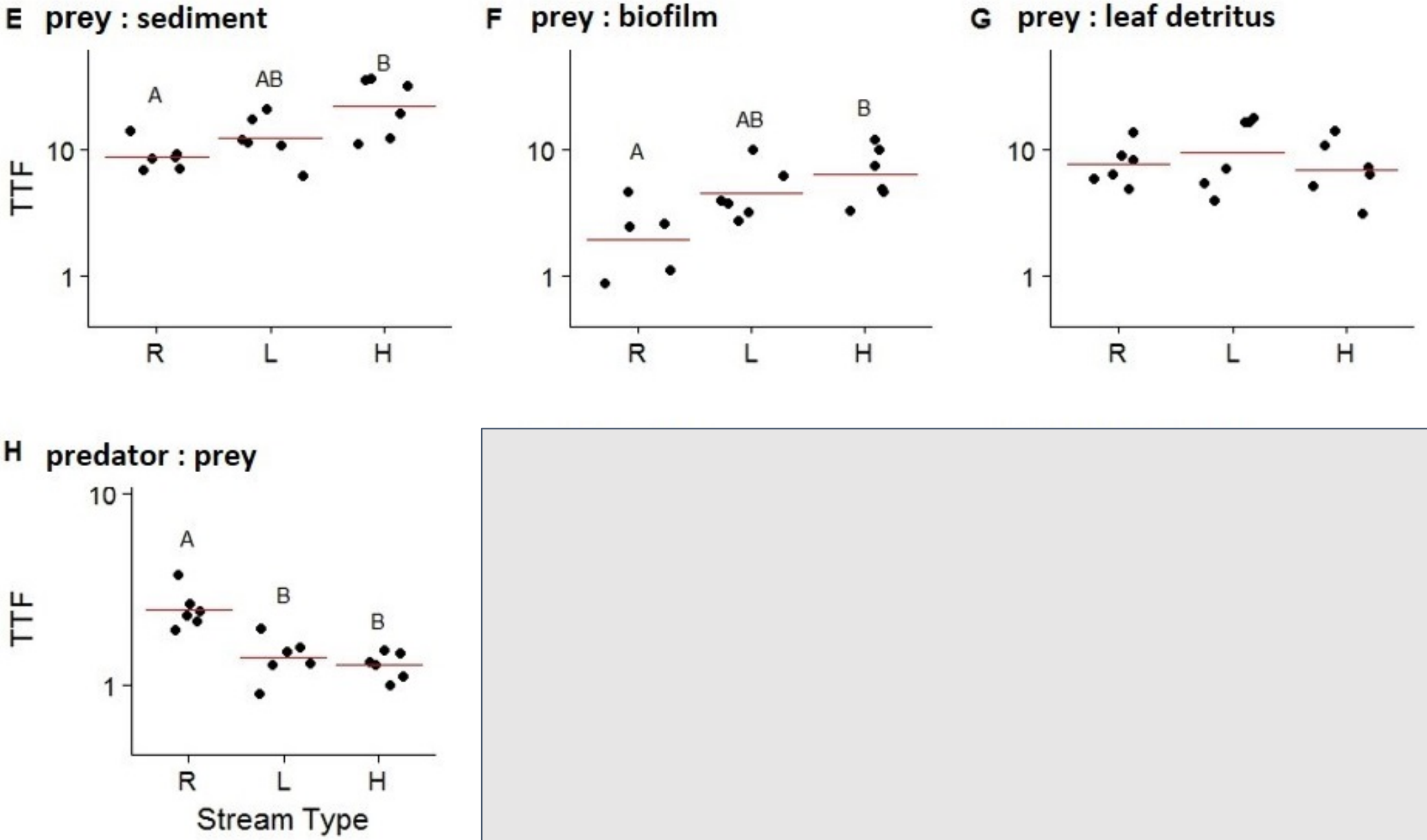






Phase II: Results – Enrichment Factors




E prey : sediment
TTF
10
1
A
AB
B
R
L
H
F prey : biofilm
10
1
A
AB
B
R
L
H
G prey : leaf detritus
10
1
R
L
H
H predator : prey
TTF
10
1
A
B
B
R
L
H
Stream Type