Trends in Bioaccumulation of Fly Ash Contaminants by Aquatic Invertebrates Downstream of the Tennessee Valley Authority Kingston Fossil Plant

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Managed by UT-Battelle for the Department of Energy

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Study Objectives

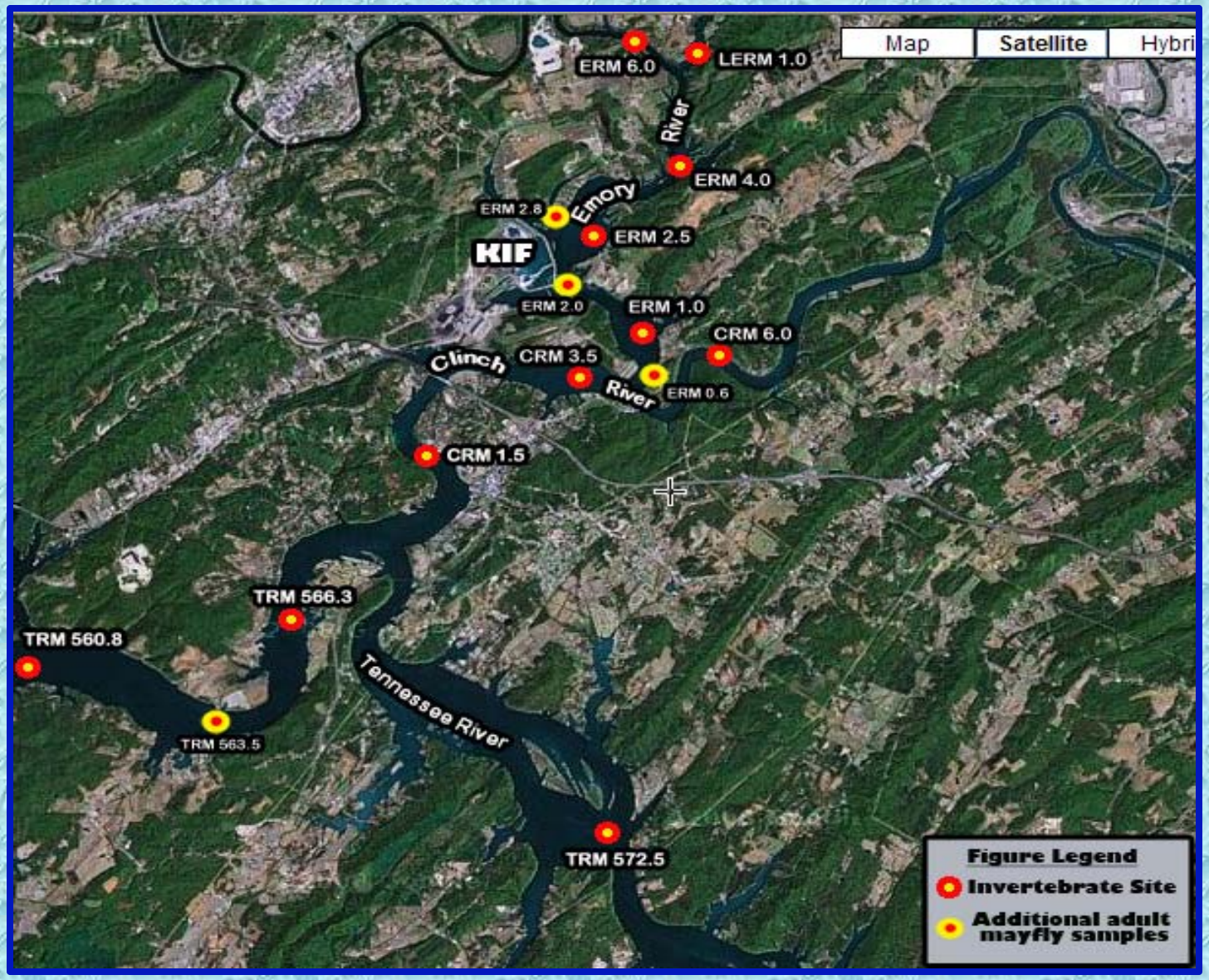
Assess spatial and temporal trends in the bioaccumulation of potential fly ash contaminants by aquatic invertebrates downstream of the Kingston Fossil Fuel Plant fly ash spill.

Target Species

Pleurocera canaliculatum
(Silty hornsnail)
Grazer/herbivore-detritivore

Hexagenia bilineata
(Borrowing mayfly)
Filter-feeder/deposit-feeder/detritivore

Sampling Locations



Field Procedures

Snails

Mayfly nymphs

Field Procedures

Mayfly adults

Mayfly mating swarm

Laboratory Processing

Snails

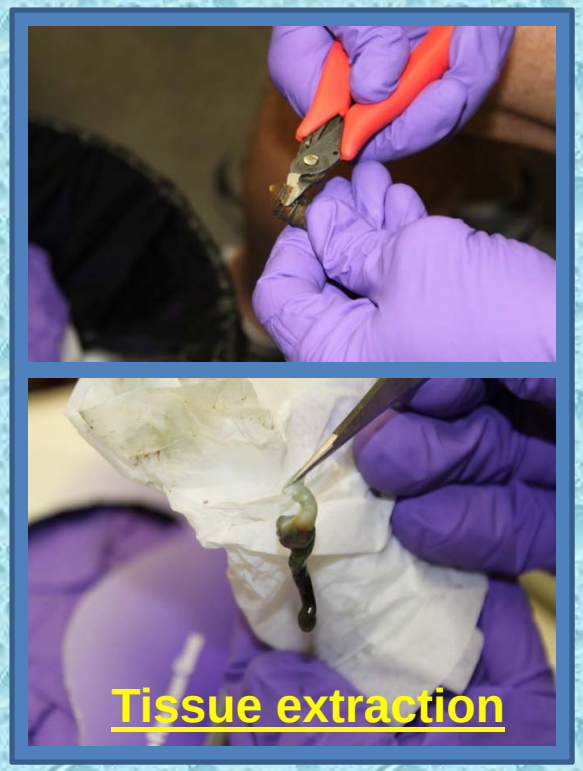
Clean snails

Depuration?

Yes

No

72 hr



Freeze/store at -°20 C

Laboratory Processing

Mayfly nymphs

Rinse thoroughly with distilled water

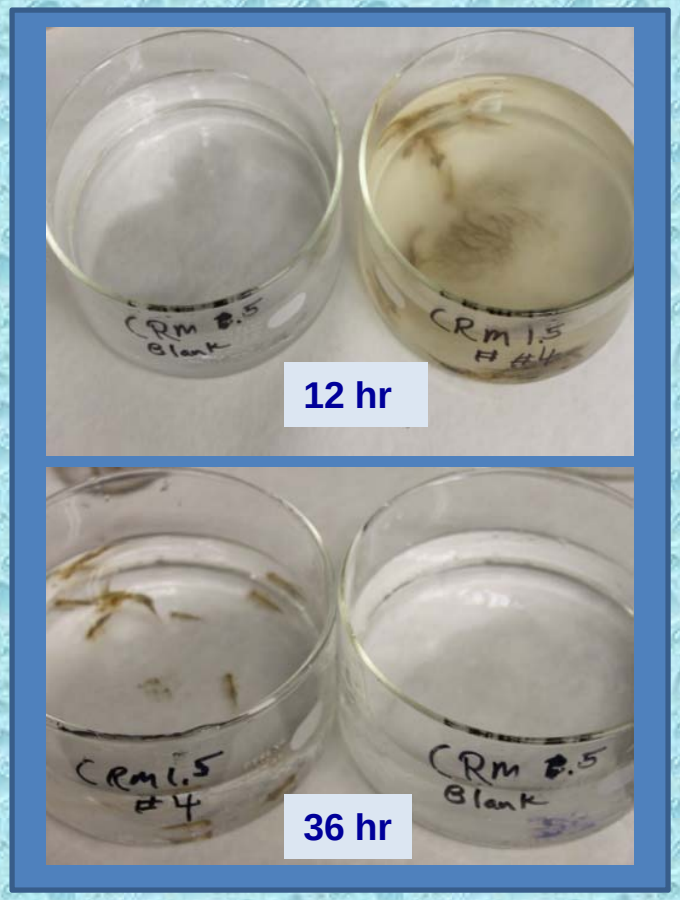
Depuration?

Yes (48 hr)

No

Non-depurated

Depurated

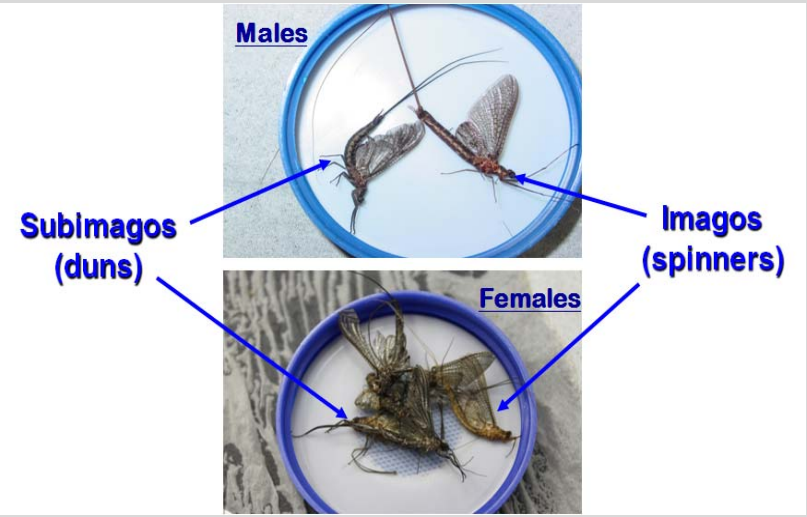


Freeze/store at -°20 C

Laboratory Processing

Mayfly adults

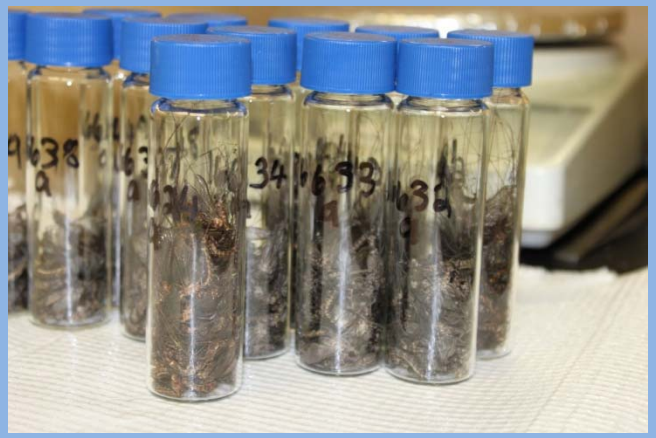
Sex and stage



Freeze/store at -°20 C

Laboratory Processing

Samples are freeze-dried



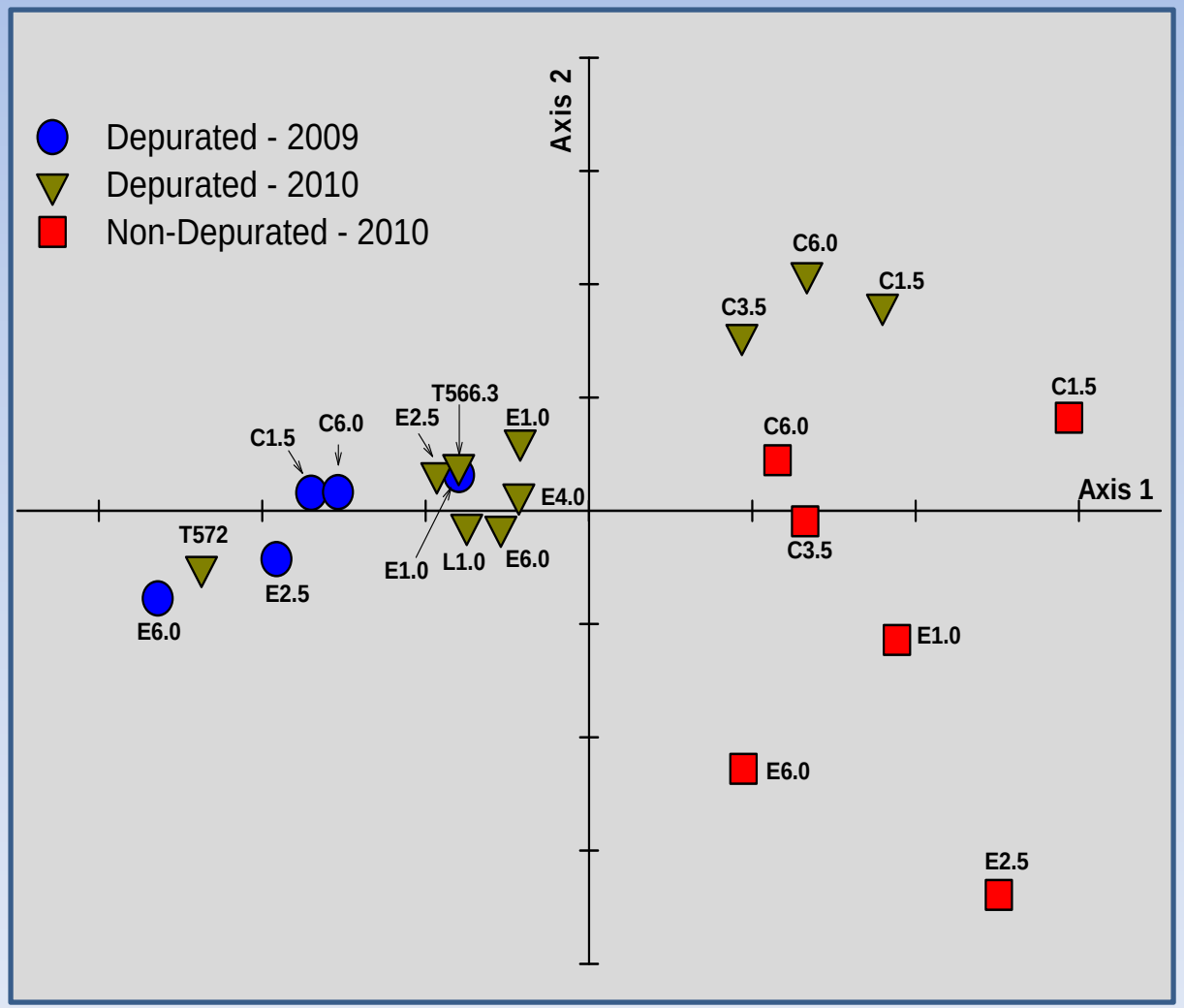
Analyzed for suite of 26 elements with EPA 6020

Samples – 2009 & 2010

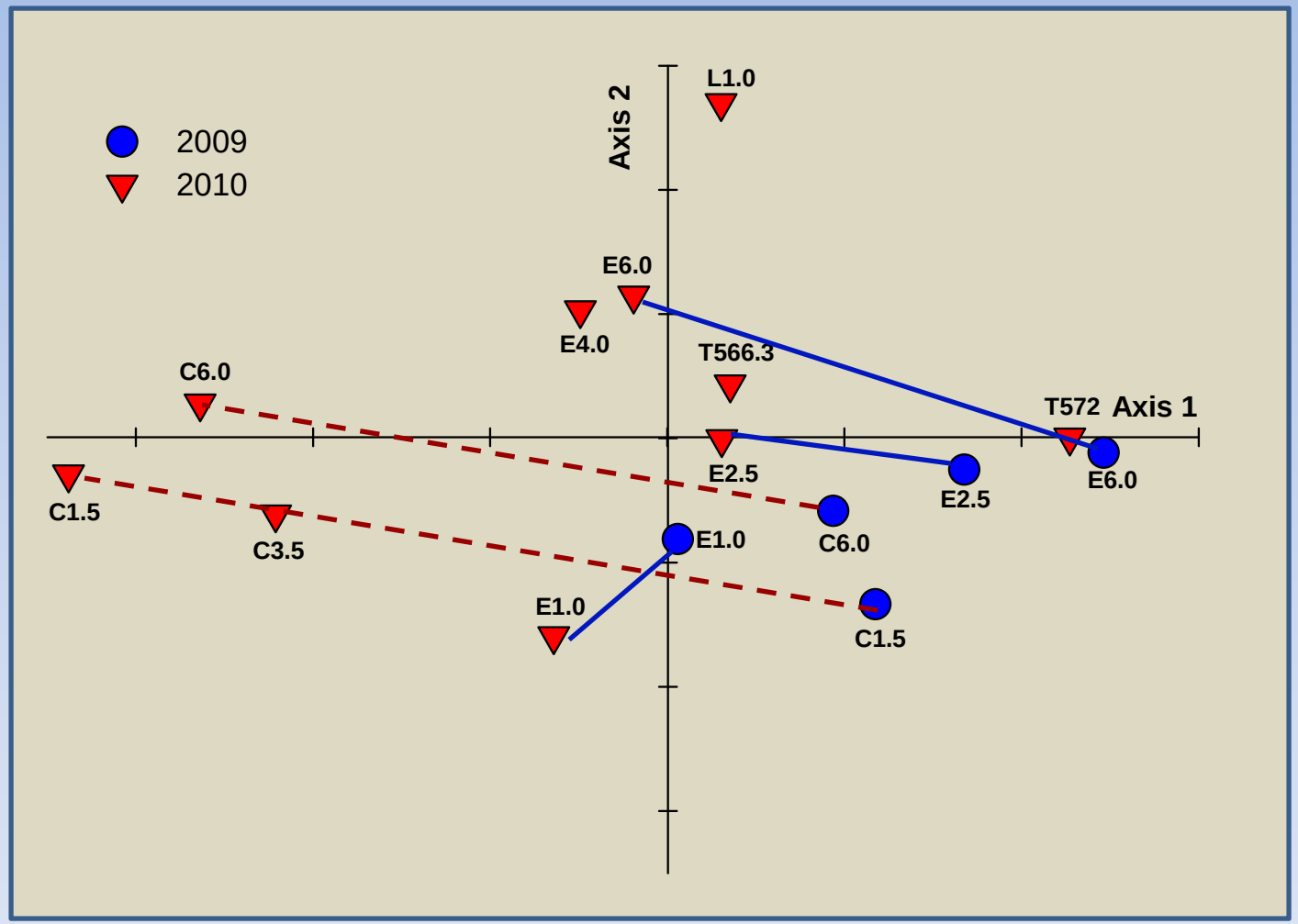
River/Site[3]	Year	Mayfly nymphs[1,2]		Mayfly adults[2]				Snails[1,2]	
				Subimagos		Imagos			
		D	ND	Female	Male	Female	Male	D	ND
Emory River									
ERM 0.6	2009	-	-	-	-	-	-	-	-
	2010	-	-	X	X	-	X	-	-
ERM 1.0	2009	X	X	-	-	-	X	X	-
	2010	X	X	X	X	-	X	X	X
ERM 2	2009	-	X	-	-	-	X	X	-
	2010	X	X	X	X	X	X	X	X
ERM 2.8	2009	-	-	-	-	-	-	-	-
	2010	-	-	-	-	X	X	-	-
ERM 4.0	2009	-	-	-	-	-	X	-	-
	2010	X	X	-	-	-	-	X	X
ERM 6.0	2009	-	X	-	-	-	-	X	-
	2010	X	X	-	-	-	-	X	X
Clinch River									
CRM 1.5	2009	X	X	-	-	X	X	X	-
	2010	X	X	-	-	X	X	X	X
CRM 3.5	2009	-	-	-	-	-	X	-	-
	2010	X	X	X	-	X	X	X	X
CRM 6.0	2009	-	X	X	X	-	-	X	-
	2010	X	X	-	-	-	X	X	X
Tennessee River									
TRM 560.8	2009	-	-	-	-	-	-	-	-
	2010	-	X	-	-	-	-	-	-
TRM 563.0	2009	-	-	-	-	-	X	-	-
	2010	-	-	X	X	-	X	-	-
TRM 567.0	2009	-	-	X	X	X	X	-	-
	2010	X	X	X	X	-	X	X	-
TRM 572.5	2009	-	-	-	-	-	-	-	-
	2010	X	X	X	X	-	X	X	-
Little Emory River									
LERM 1.0	2009	-	X	-	-	X	X	-	-
	2010	-	X	-	-	-	-	X	-

[1]"ND" = not depurated; "D" = depurated.
[2]Mayfly nymphs and adults = *Hexagenia bilineata*; snails = *Pleurocera canaliculatum*.
[3]ERM = Emory River mile; CRM = Clinch River mile; TRM = Tennessee River mile; LERM = Little Emory River mile.

Principal Components Analysis – Snails 2009 & 2010

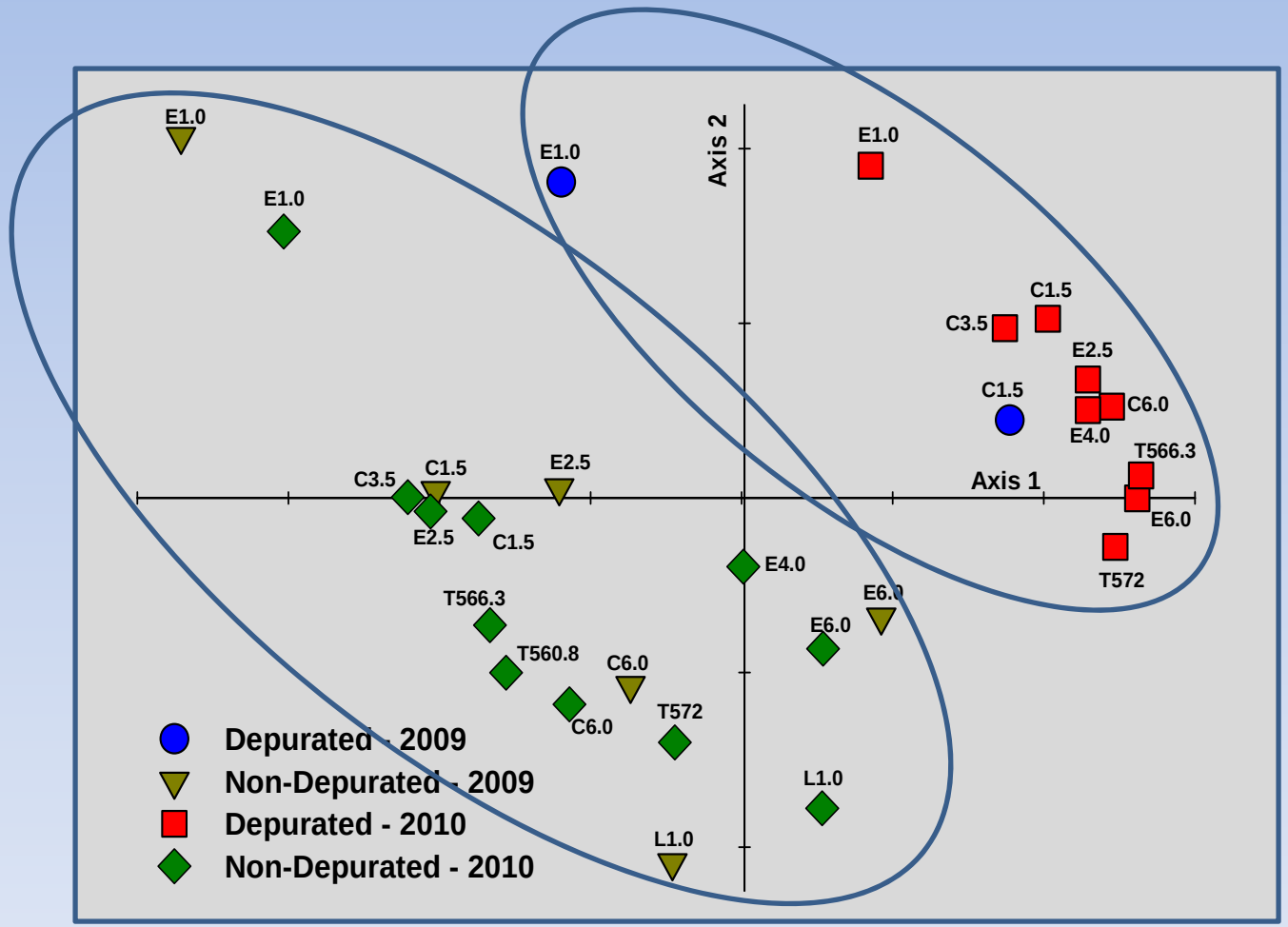


Principal Components Analysis
Depurated Snails Only – 2009 & 2010*

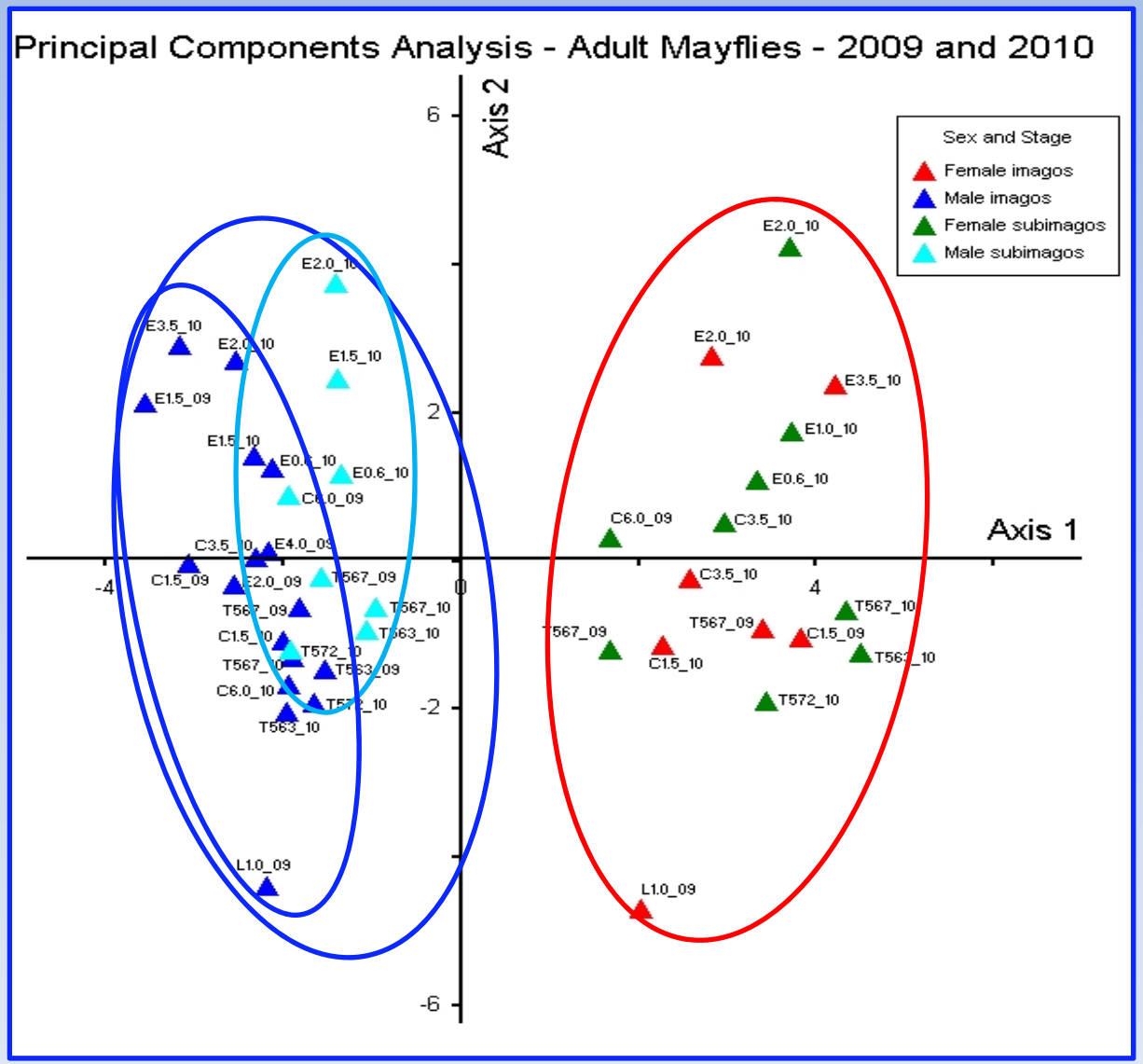


*(Blue and red lines join Emory River and Clinch River sites, respectively, between years)

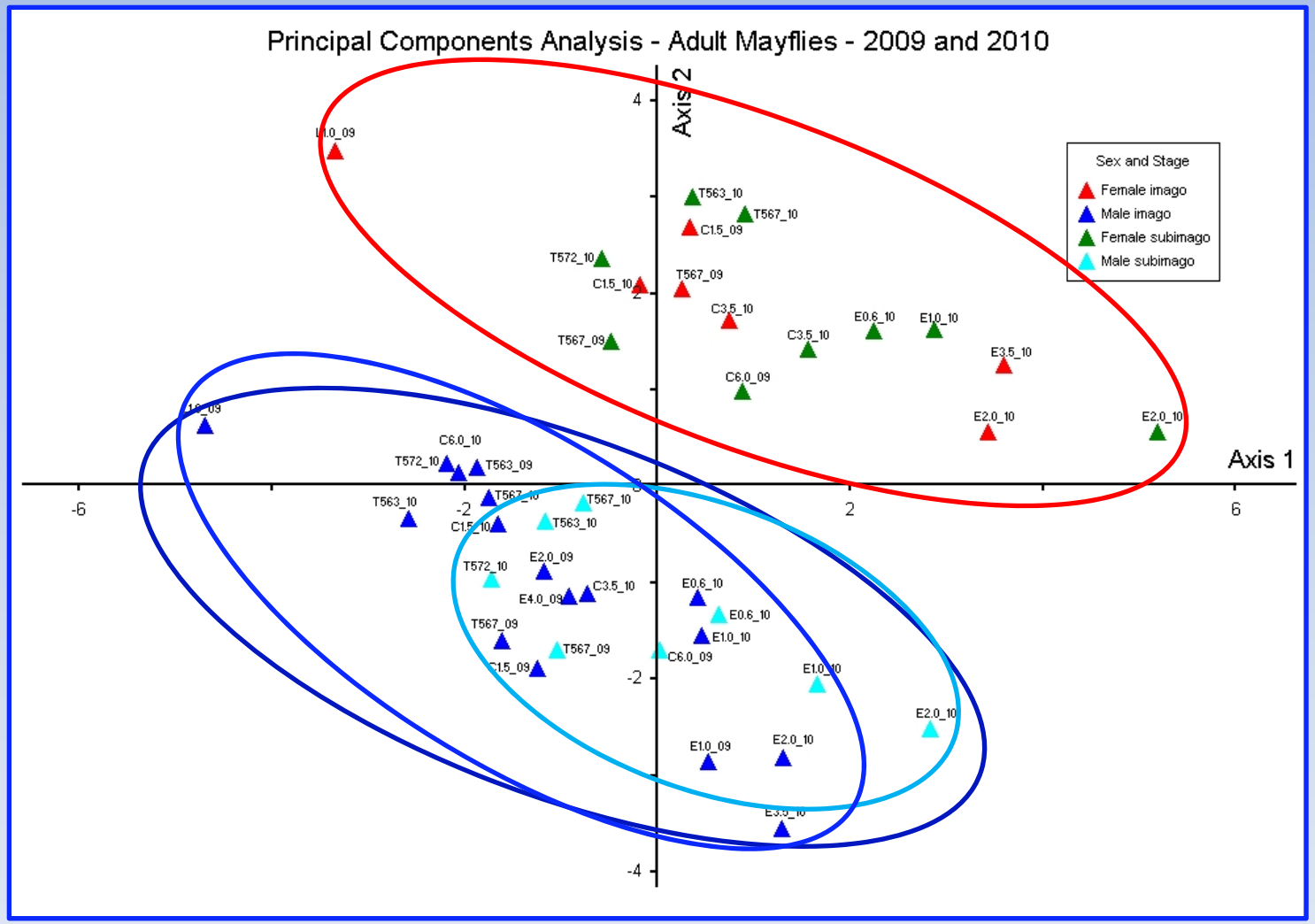
Principal Components Analysis – Mayfly Nymphs 2009 & 2010



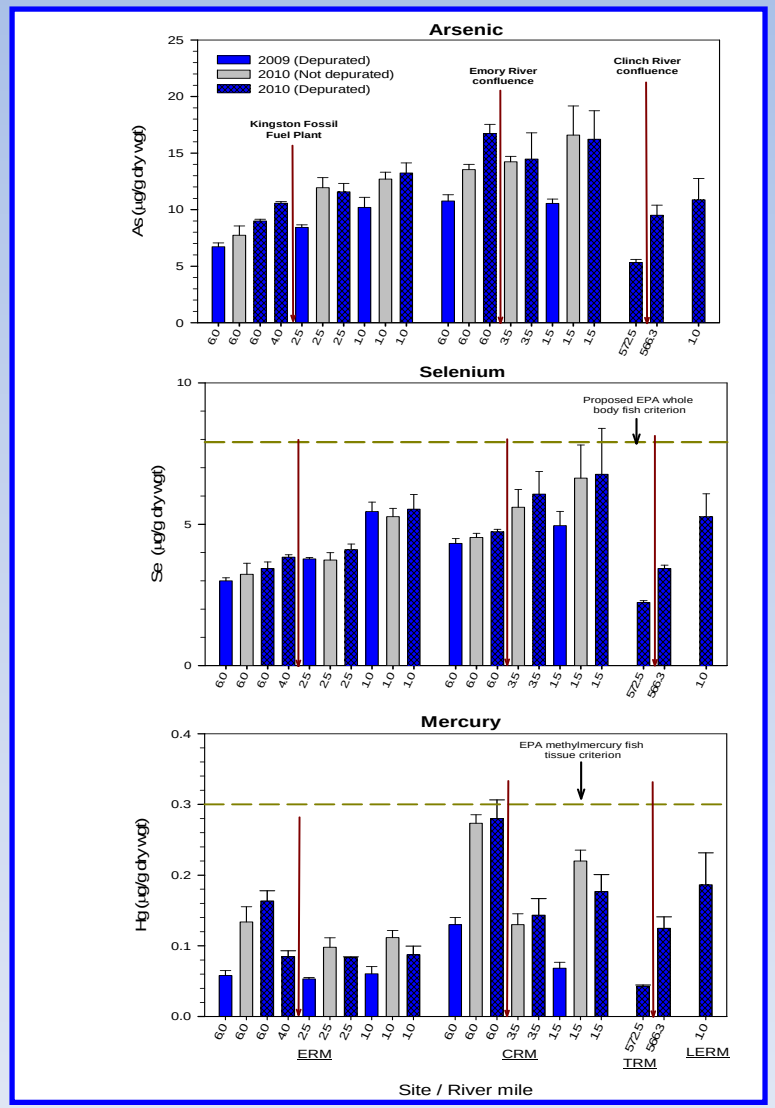
Principal Components Analysis – Adult Mayflies 2009 & 2010



Principal Components Analysis – Adult Mayflies Excluding Ca, Fe, Mg, Mn, K, Na - 2009 & 2010

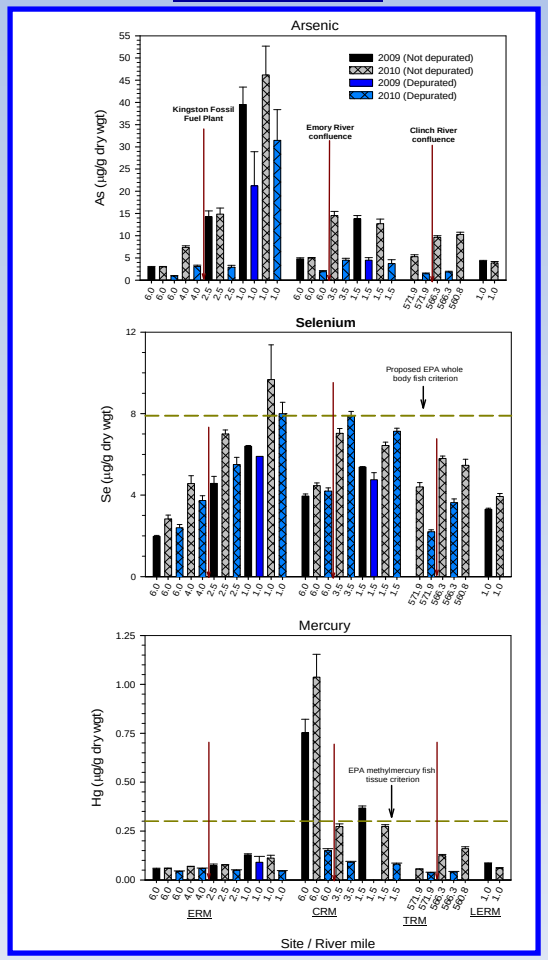


Concentrations of As, Se, and Hg – Snails 2009 & 2010

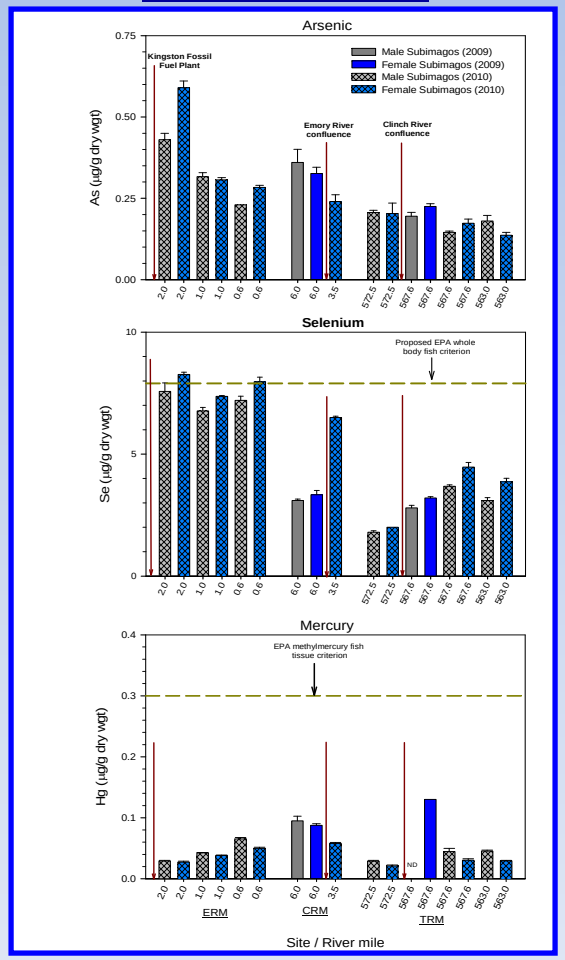


Concentrations of As, Se, and Hg – Mayflies 2009 & 2010

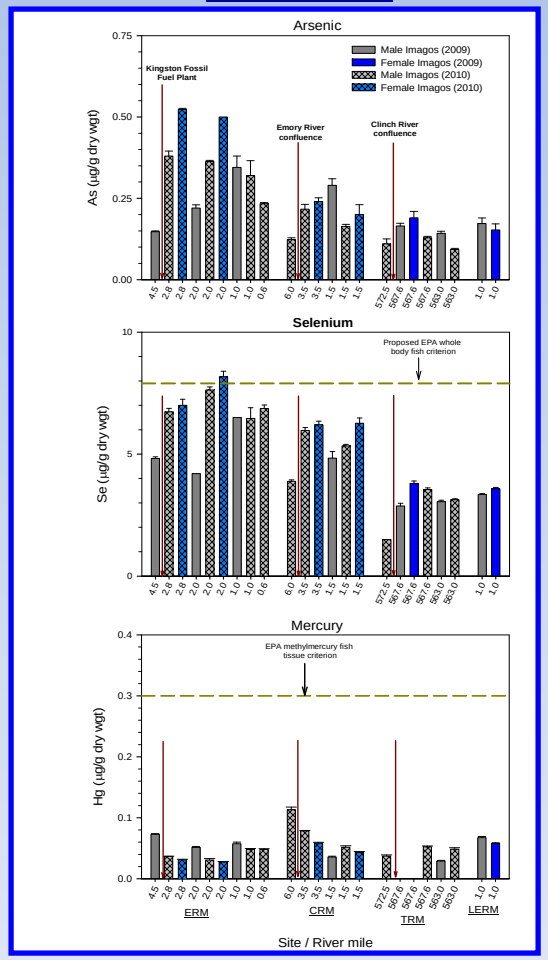
Nymphs



Subimagos



Imagos



Conclusions - General

- Highest concentrations of elements for all groups generally in Emory and Clinch Rivers downstream of the spill site

- Highest concentrations of many elements in mayfly nymphs typically at ERM 1.0

- Highest concentrations of many elements in adults typically adjacent to the spill site (i.e., around ERM 2.0)

- Highest concentrations of many elements in snails generally at Clinch River sites (CRM 1.5 and CRM 6.0)

Conclusions - General

- Spatial trends were generally stronger than temporal trends, and they appeared to be similar between years

- Depuration had a significant effect on concentrations of most elements (e.g., Cd, Cu, and Zn were higher in both species)

- Bioaccumulation of some elements is clearly different in male and female mayflies

- Differences between male imagos and subimagos appear to be related mostly to differences in concentrations of essential elements

Conclusions – Arsenic

- Highest concentrations generally found in mayfly nymphs

- Depurated versus non-depurated snails suggest As may be bioaccumulating in tissue

- Depurated versus non-depurated mayfly nymphs suggest less tissue bioaccumulation than in snails

- Amount of As leaving the water via adult mayflies is minimal (but does this apply to all insects?)

- Primary source of As appears to be KIF fly ash, but there may be secondary source in Clinch River

Conclusions – Selenium

- Concentrations highest in mayfly nymphs and lowest in snails
- Concentrations generally only slightly lower in adult mayflies than the nymphs
- Depuration had minimal effect on concentrations in snails and nymphs
- Primary source of Se appears to be KIF fly ash
- Concentrations in snails appeared to increase with distance downstream from ERM 2.5 to CRM 1.5
- Concentrations declined downstream of ERM 1.0 in nymphs, and downstream of ERM 2 in the adults

Conclusions – Mercury

- All three groups indicated that the primary source of Hg is the Clinch River upstream of CRM 6.0

- Only contaminant that showed similar spatial trends among all three groups

- Depuration had little effects on concentrations of Hg in snails

- Depuration drastically reduced concentrations in nymphs from Clinch River sites, but not the Emory River sites

- Concentrations in adult mayflies were considerably lower than in the nymphs

Questions

- What factors are contributing to differences between snails and mayfly nymphs? (physiological, environmental)

- How much are native soils contributing to element concentrations?

- What effects do natural differences in water quality of the three rivers have on availability, transport and fate of contaminants?