Implications of fish-habitat relationships for designing restoration projects within channelized agricultural headwater streams

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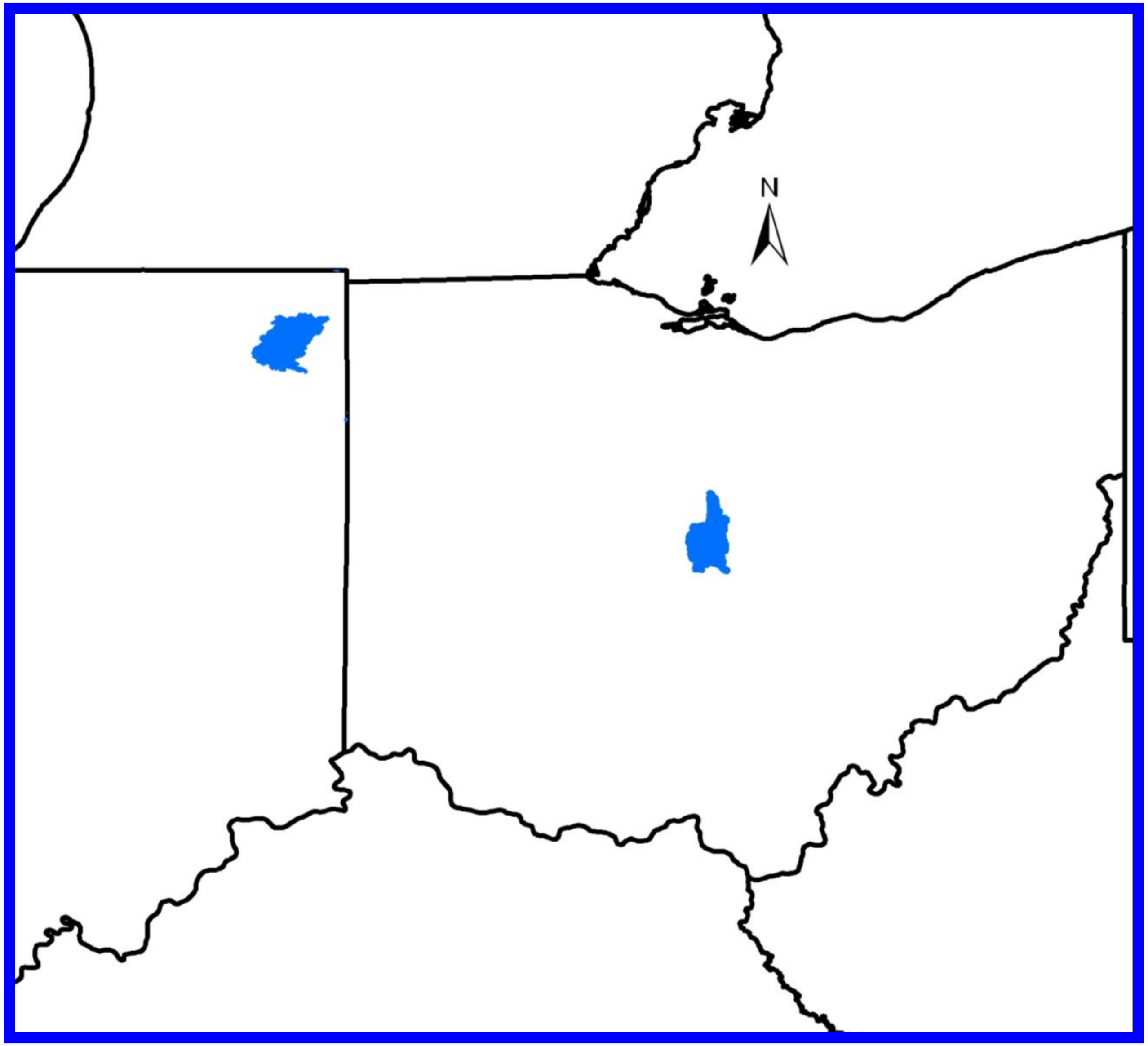
Cedar Creek

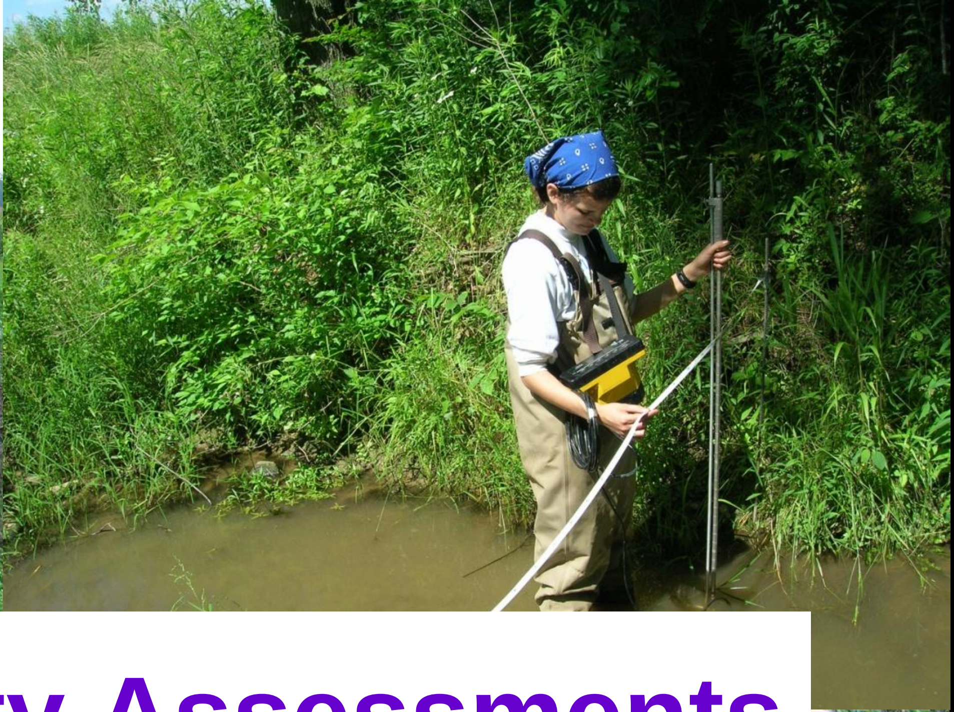
- Located in northeast Indiana
- Sampling seven sites in three channelized streams
- Watershed sizes range from 3 to 25 km^2

Upper Big Walnut Creek

- Located in central Ohio
- Sampling 14 sites in seven channelized streams
- Watershed sizes range from 0.6 to 10 km^2

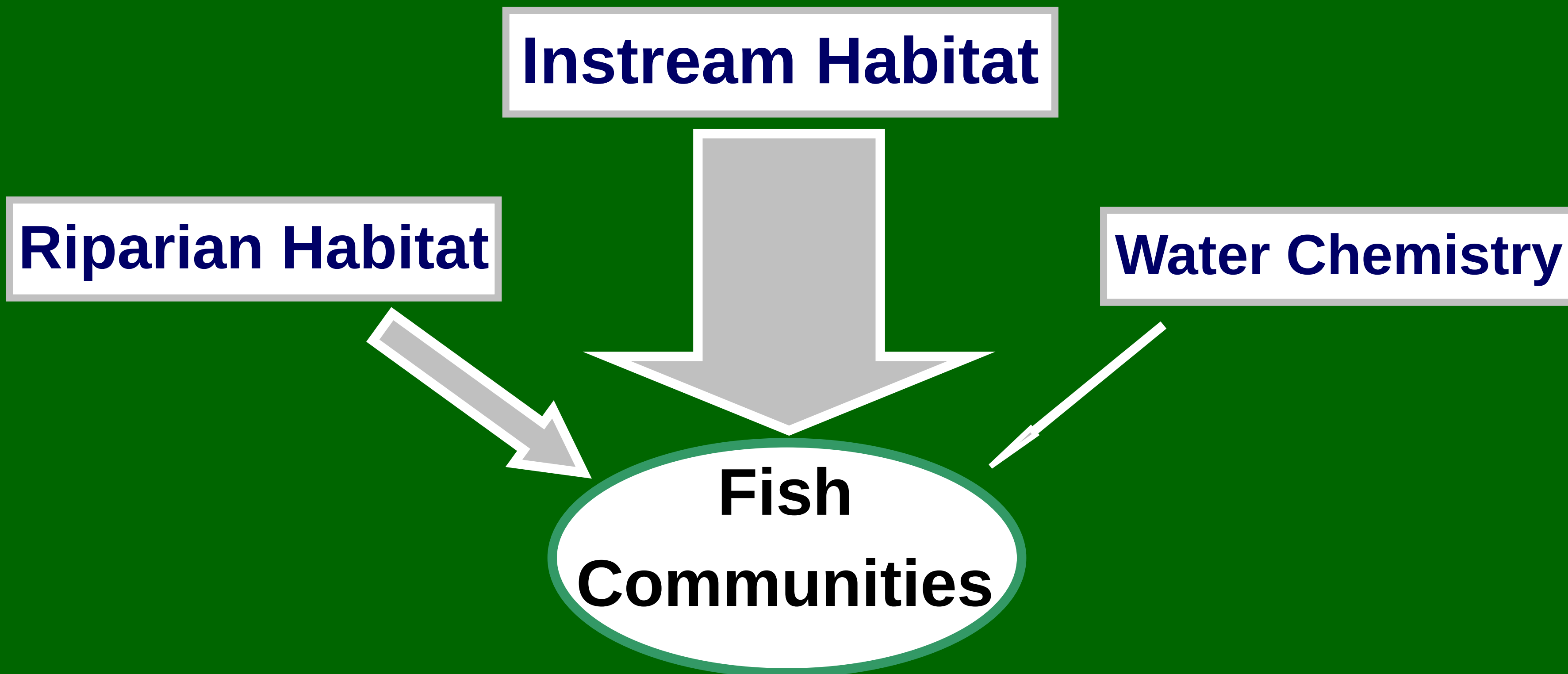



Cedar Creek
Upper Big Walnut Creek

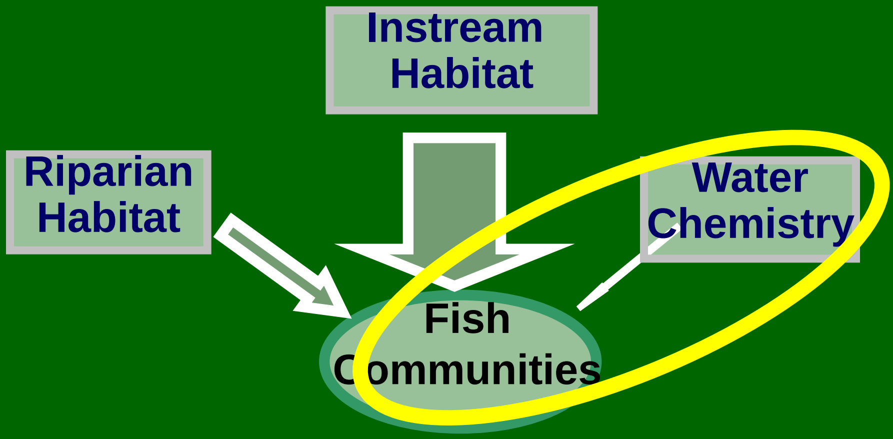
Fish Community Assessments


Initial Fish-Habitat Relationship Assessments (2005 to 2006)



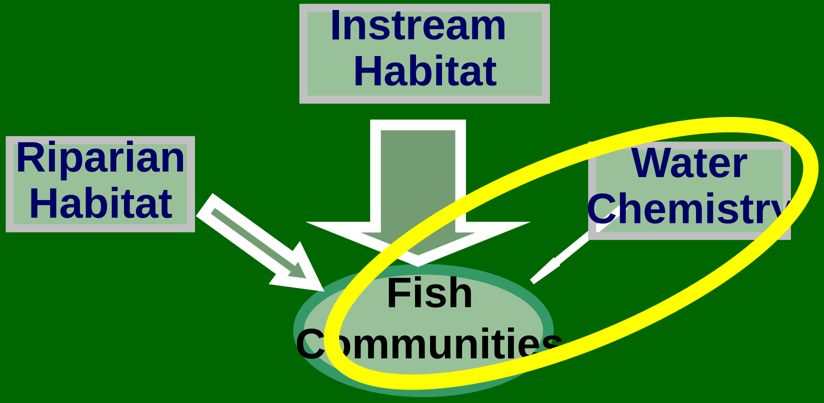
Smiley et al. 2008. Journal of Soil and Water Conservation 63: 218A-219A

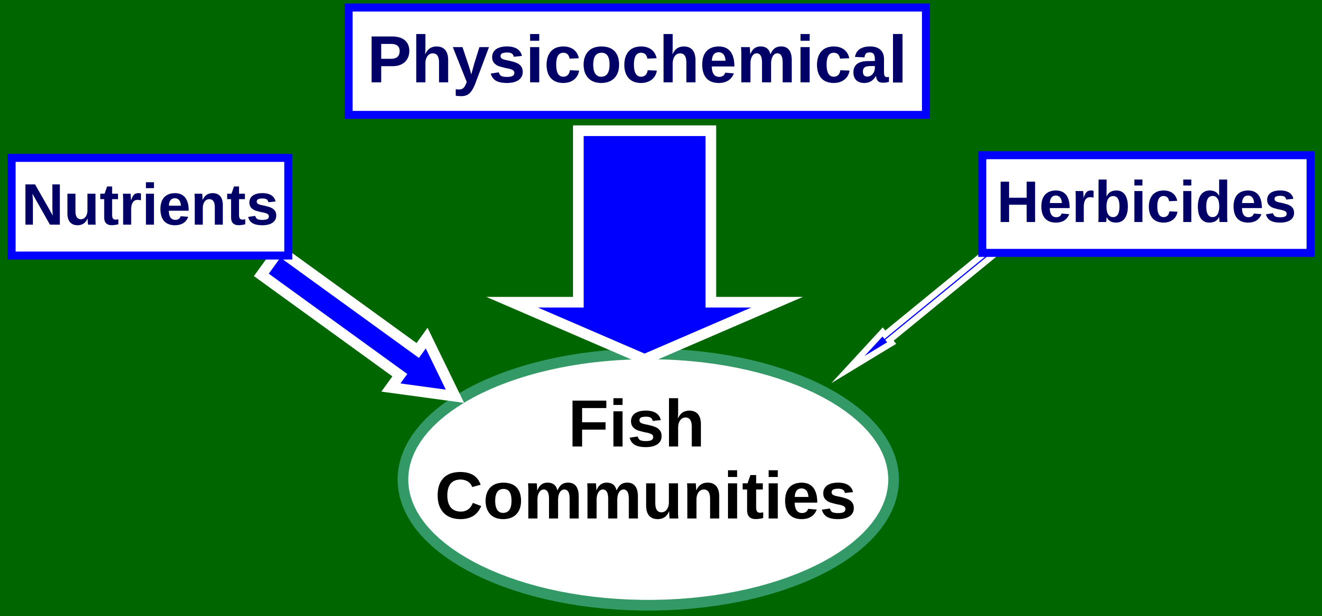
Initial Fish-Habitat Relationship Assessments (2005 to 2007)



Smiley et al. 2009. Ecohydrology 2: 294-302

Initial Fish-Habitat Relationship Assessments (2005 to 2007)





Smiley et al. 2009. Ecohydrology 2: 294-302

Cross-watershed Comparisons of Fish-Habitat Relationships (2006 to 2010)

- Given the differences in fish species composition and locality
  - Do fish-habitat relationships differ between Cedar Creek and Upper Big Walnut Creek watersheds?
  - Does watershed size influence fish-habitat relationships?

	CC (- loadings)	CC (+ loadings)	UBWC (- loadings)	UBWC (+loadings)
Riparian Habitat Axis 1		% Woody Veg. Ratio WV: HV WV Struct. Rich.	% Woody Veg. Ratio WV: HV Mean % canopy SD % canopy	
Riparian Habitat Axis 2	% Herb. Veg. Herb. Veg. Rich.		% Herb. Veg. Herb. Veg. Rich.	
Instream Habitat Axis 1	% Gravel Velocity	% Clay % Silt		M Depth SD Depth M Wet Width SD Wet Width
Instream Habitat Axis 2	% Cobble Discharge		% Gravel % Sand	Mean Depth
Water Chemistry Axis 1	Atrazine		SRP Total Phosphorus Nitrate+Nitrite	pH
Water Chemistry Axis 2	Total Phosphorus	Conductivity		Metolachlor Atrazine

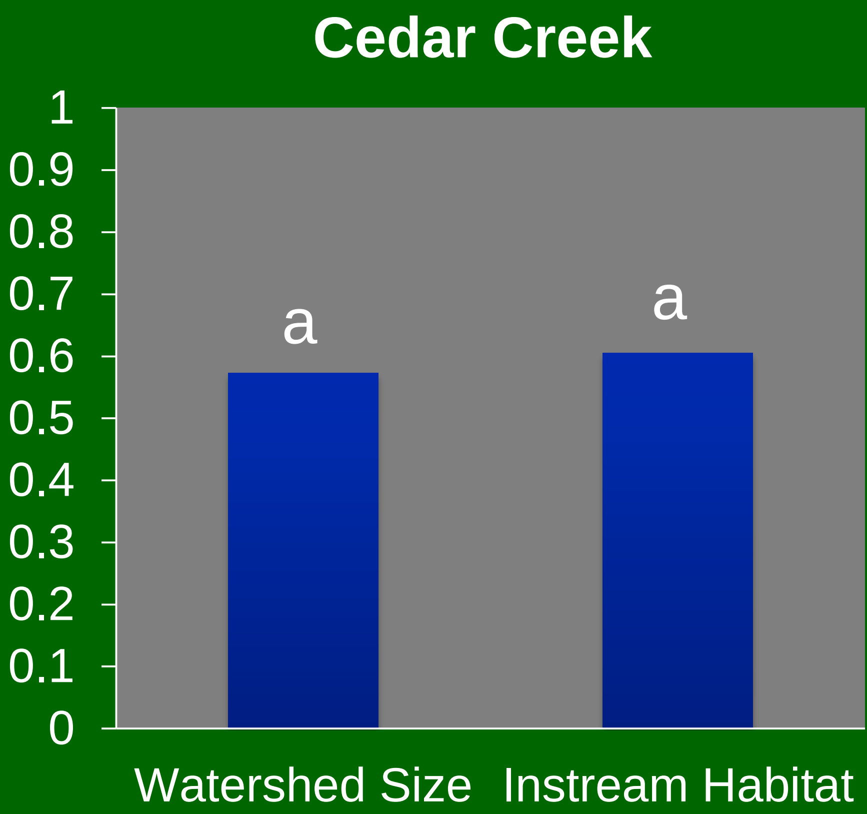
Number of RV with Greatest Standardized Coefficients

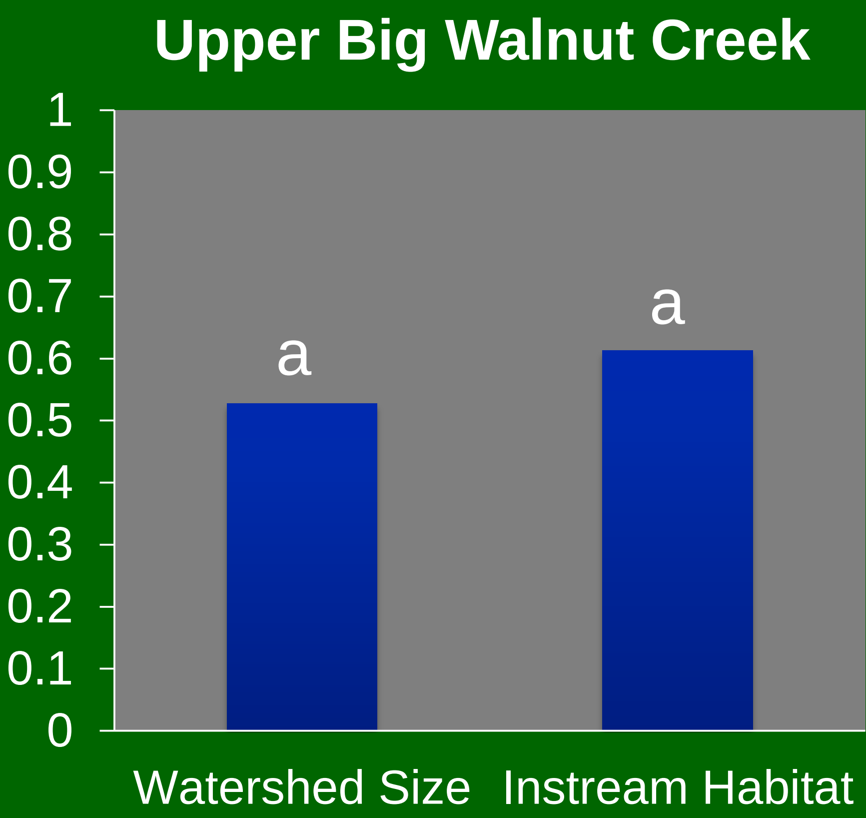
	CC # Response Variables	UBWC # Response Variables
Riparian Habitat PCA Axis 1	4	1
Riparian Habitat PCA Axis 2	0	3
Instream Habitat PCA Axis 1	11	13
Instream Habitat PCA Axis 2	0	2
Water Chemistry PCA Axis 1	4	1
Water Chemistry PCA Axis 2	2	0

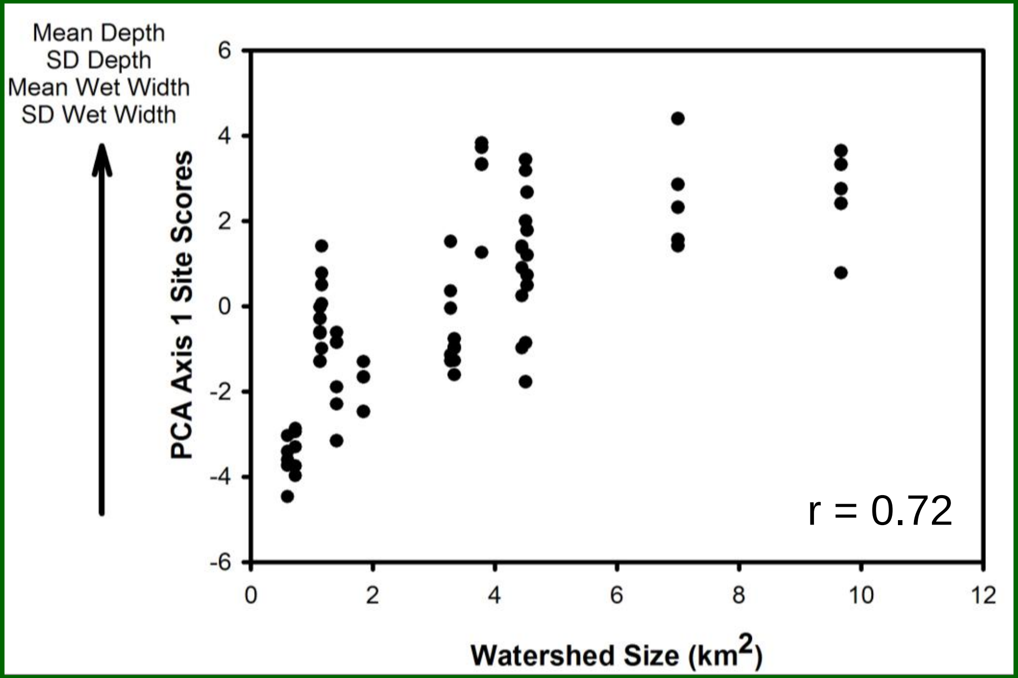
Correlations between Habitat Gradients and Watershed Size

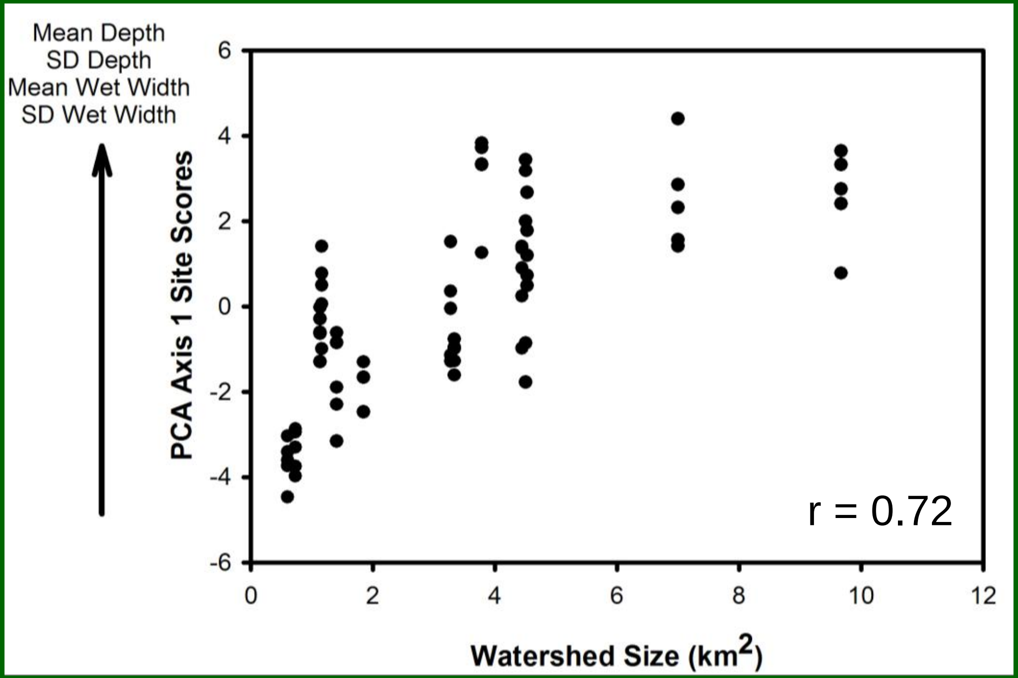
	CC r values (P values)	UBWC r values (P values)
Riparian Habitat Axis 1 & Watershed Size	-0.31 (0.08)	-0.20 (0.10)
Riparian Habitat Axis 2 & Watershed Size	-0.07 (0.70)	**-0.39 (0.001)**
Instream Habitat Axis 1 & Watershed Size	***-0.76 (< 0.001)***	***0.72 (< 0.001)***
Instream Habitat Axis 2 & Watershed Size	**0.40 (0.02)**	0.23 (0.10)
Water Chemistry Axis 1 & Watershed Size	0.03 (0.85)	0.09 (0.56)
Water Chemistry Axis 2 & Watershed Size	0.29 (0.11)	0.09 (0.48)

Mean r Values of Selected Fish Response Variables with Watershed Size and Instream Habitat Axis 1

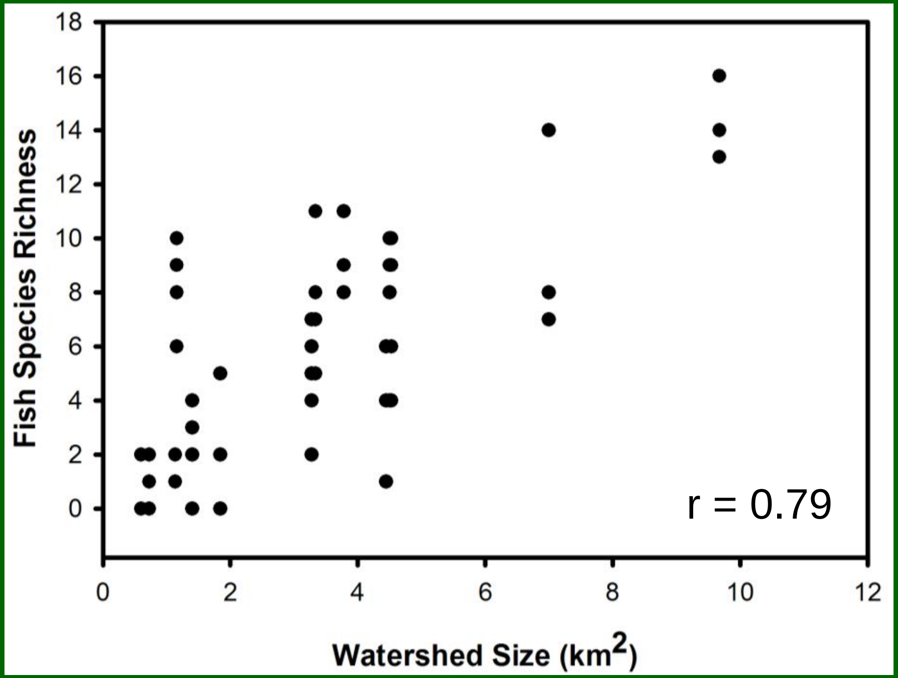




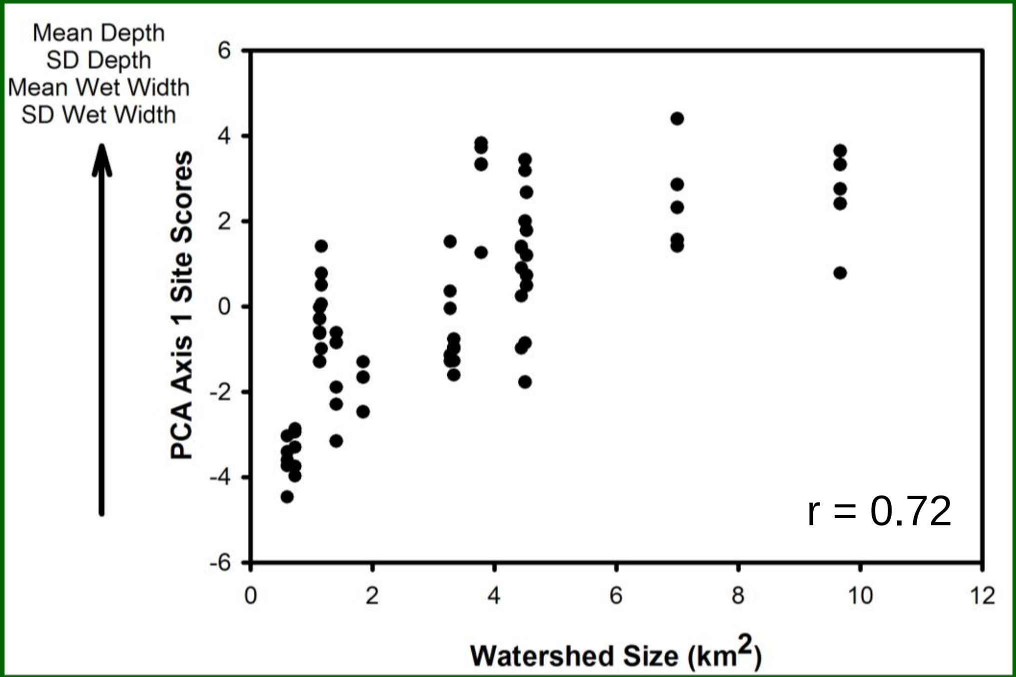

Mean Depth
SD Depth
Mean Wet Width
SD Wet Width
PCA Axis 1 Site Scores
Watershed Size (km2)
r = 0.72
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12



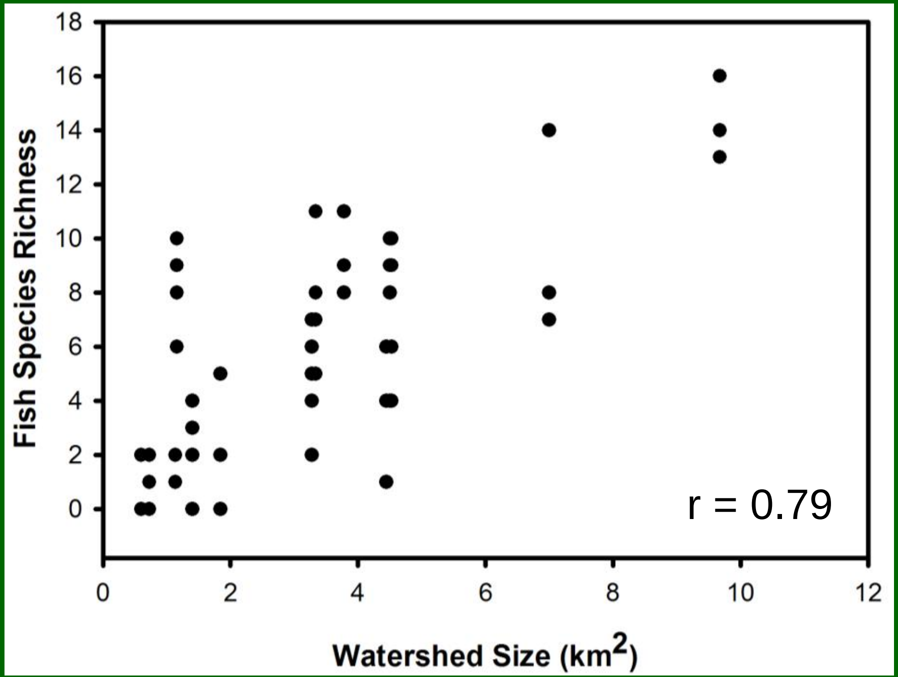
Mean Depth
SD Depth
Mean Wet Width
SD Wet Width
PCA Axis 1 Site Scores
6
4
2
0
-2
-4
-6
0
2
4
6
8
10
12
Watershed Size (km^2)
r = 0.72



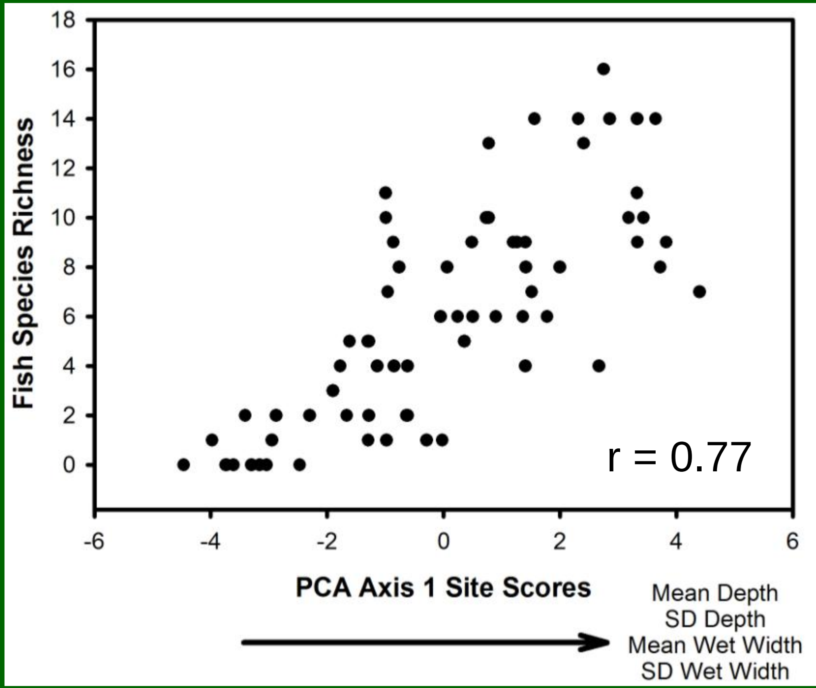
Fish Species Richness
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
Watershed Size (km^2)
r = 0.79



Mean Depth
SD Depth
Mean Wet Width
SD Wet Width
PCA Axis 1 Site Scores
Watershed Size (km^2)
r = 0.72



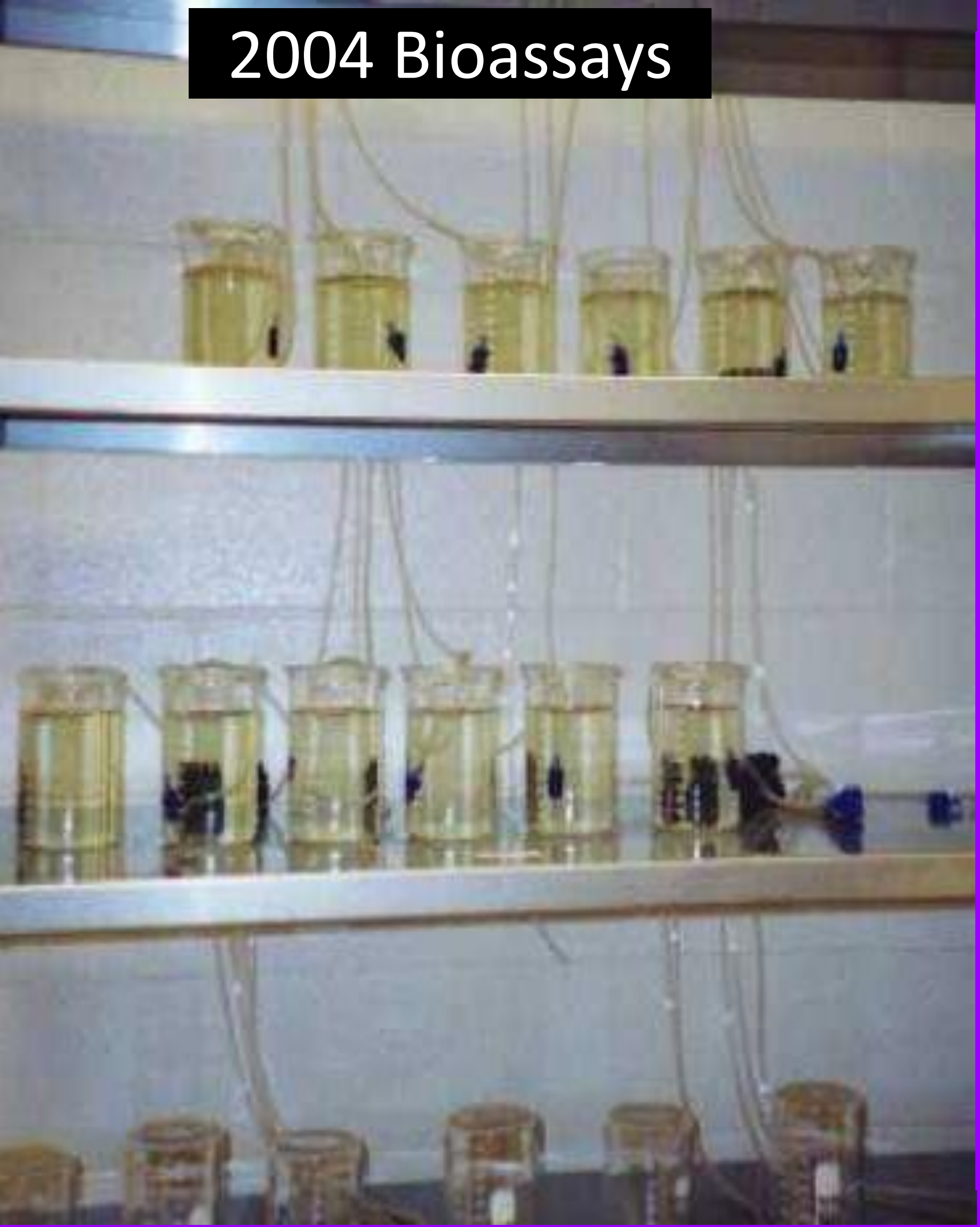
Fish Species Richness
Watershed Size (km^2)
r = 0.79



Fish Species Richness
PCA Axis 1 Site Scores
Mean Depth
SD Depth
Mean Wet Width
SD Wet Width
r = 0.77

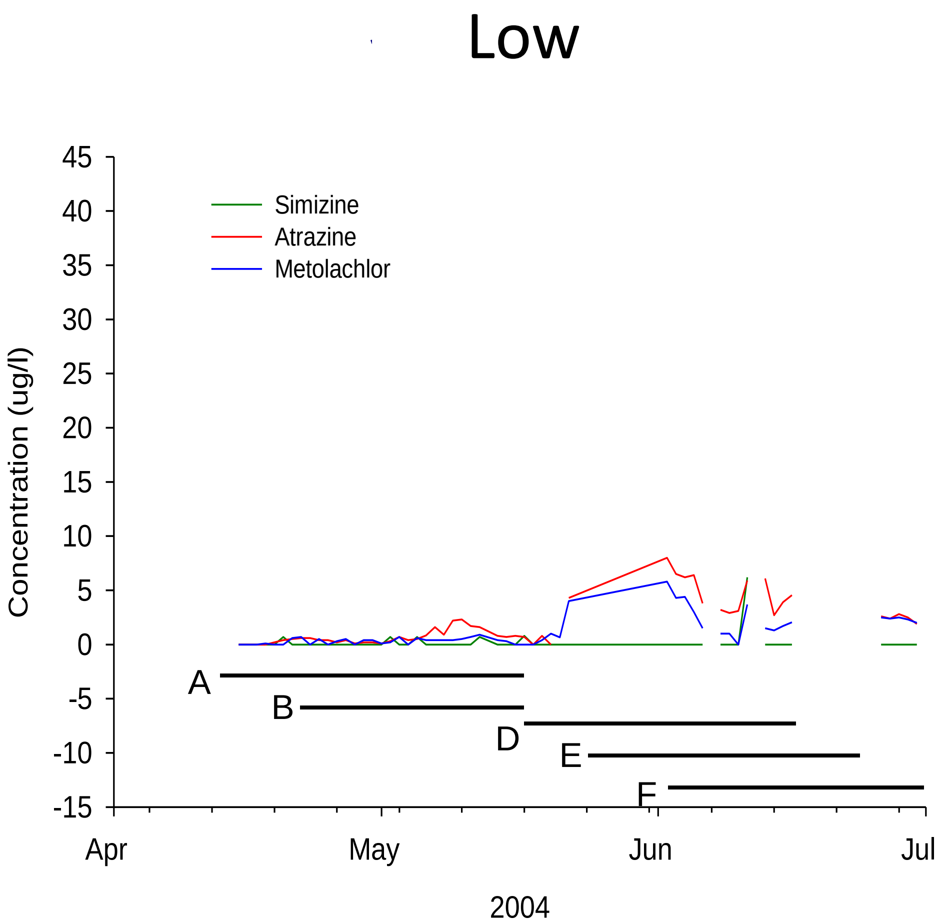

Bioassays

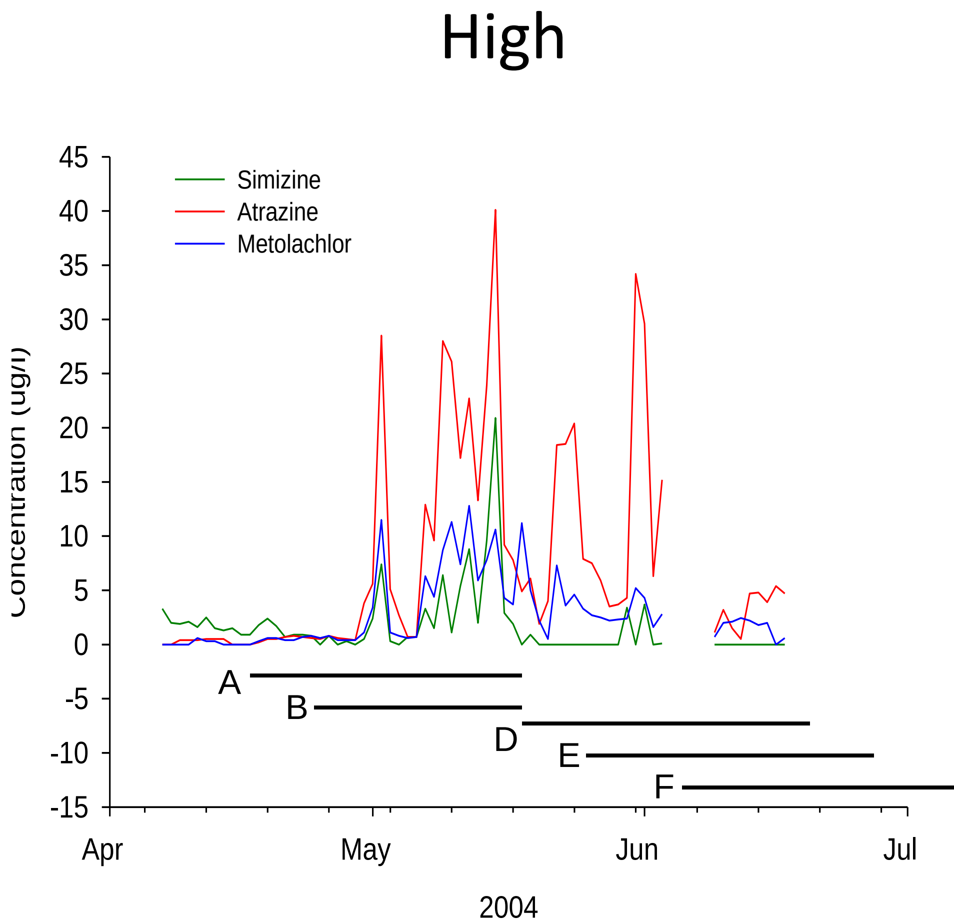
2004 Bioassays

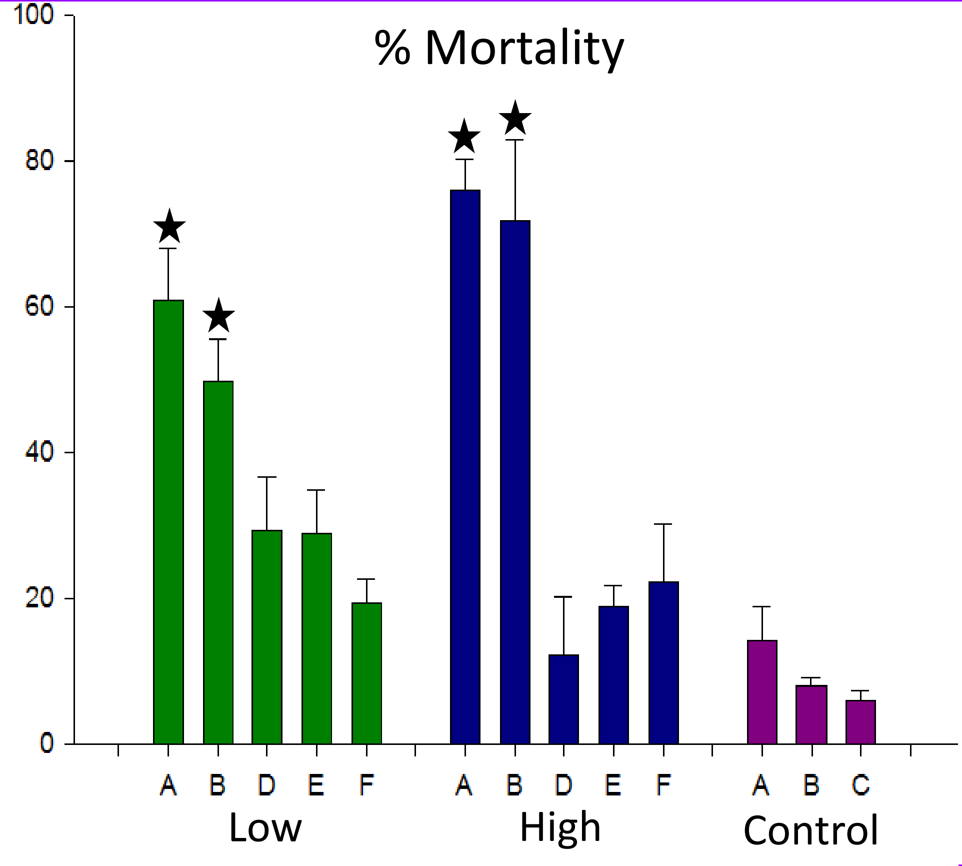


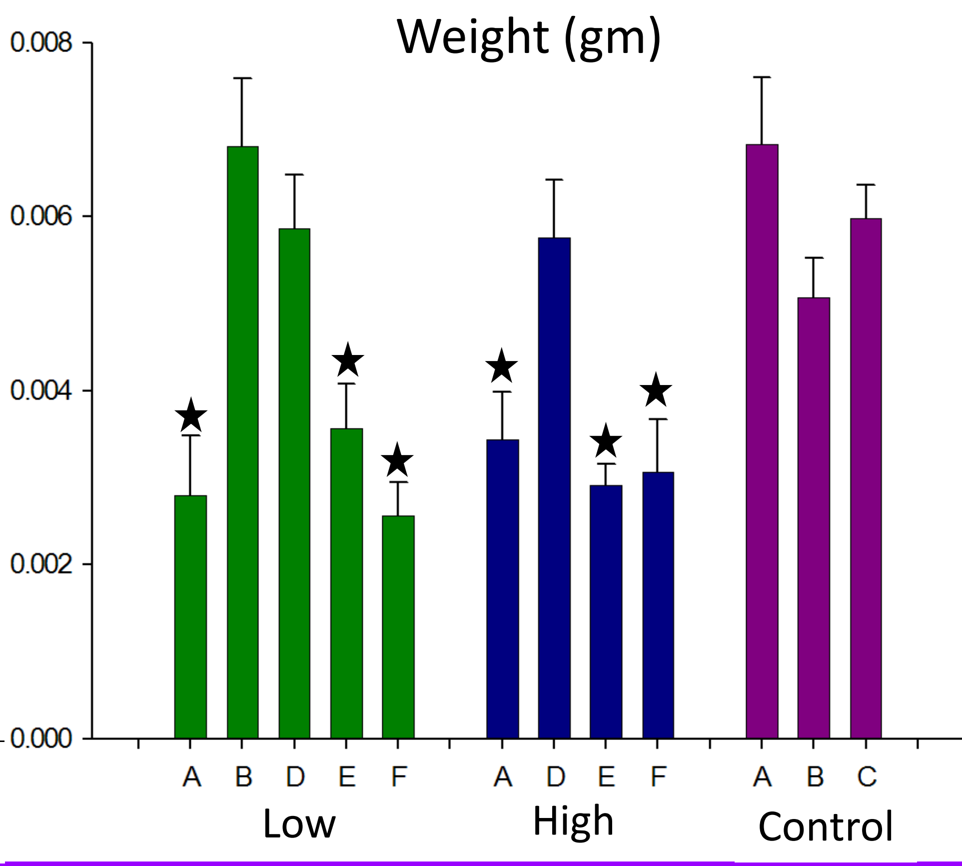
- Series of bioassays from April to June 2004
- Fathead minnows exposed to water from streams with low and high pesticide concentrations
- Exposed 30 days and then transferred to tap water for 122 days post-exposure

Pesticide Concentrations during 2004 Bioassays





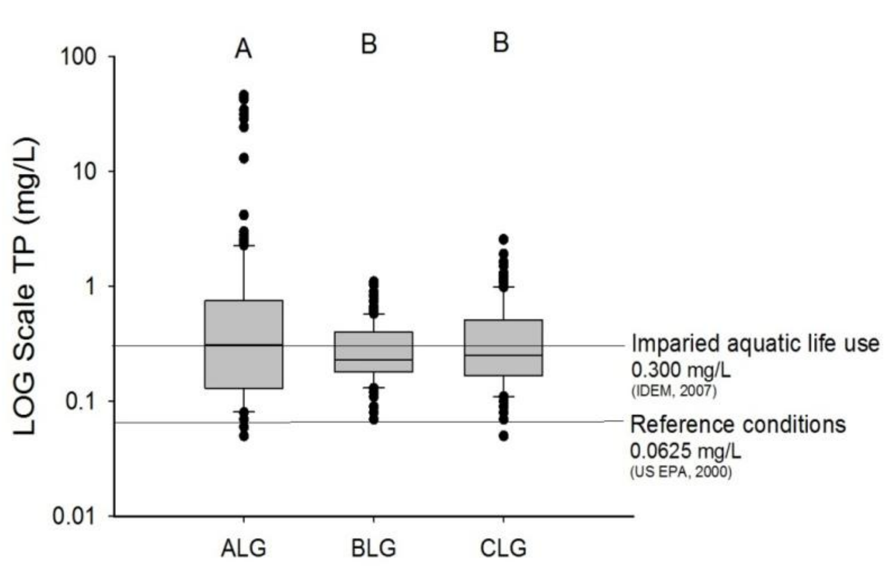


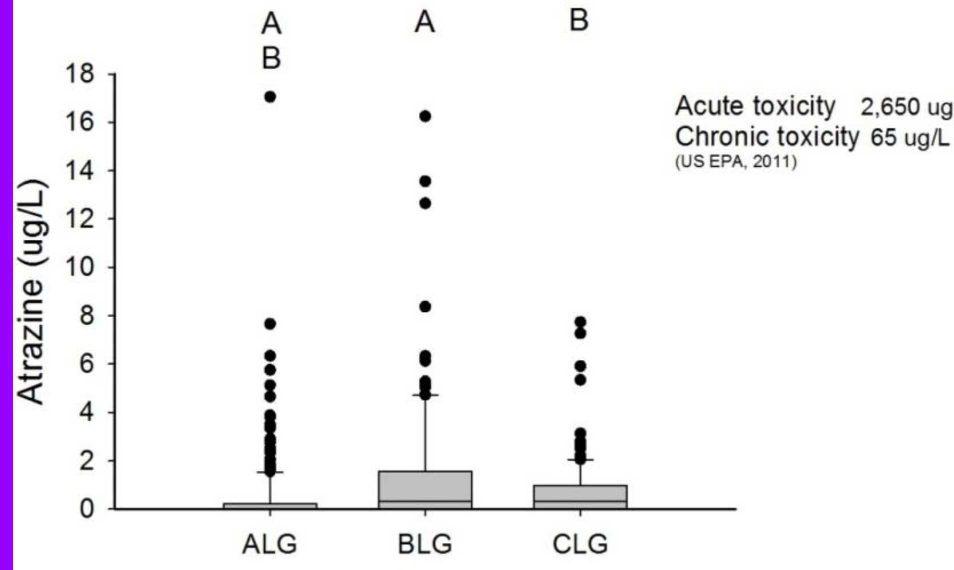


- No differences in hepatosomatic index, gonadosomatic index, proportion sexually mature fish, or vittelogenin levels

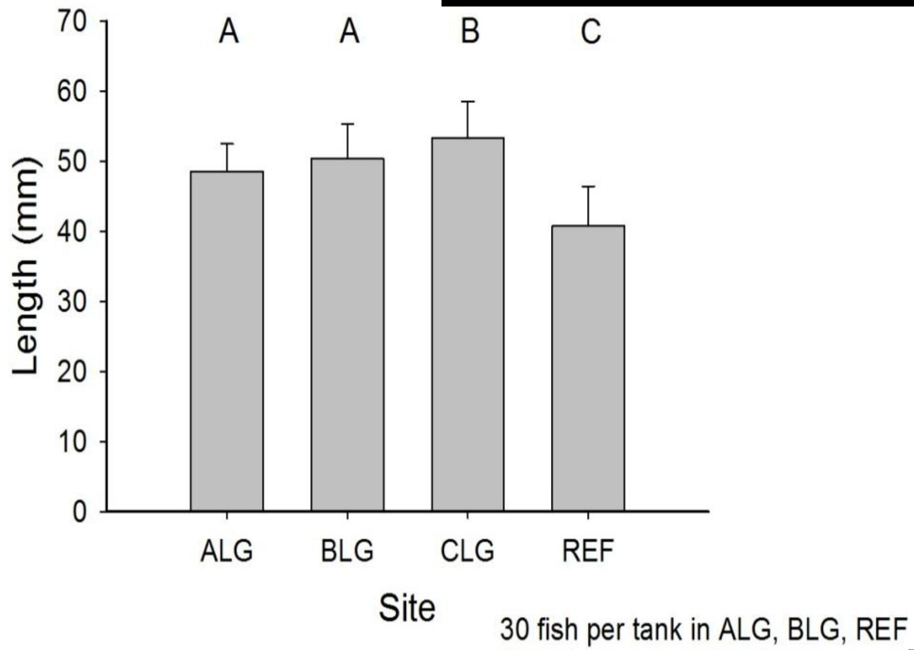
2010 Bioassays

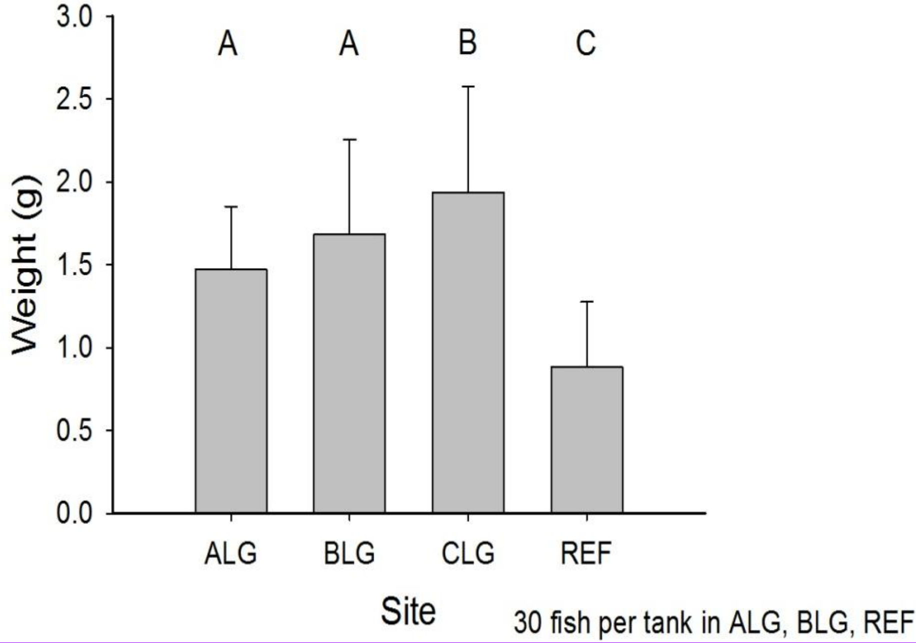
- Larval fathead minnows exposed to water from 3 streams
- 8 weeks post-hatch fathead minnows transferred to streamside bioassays
- Exposed from May to September 2010





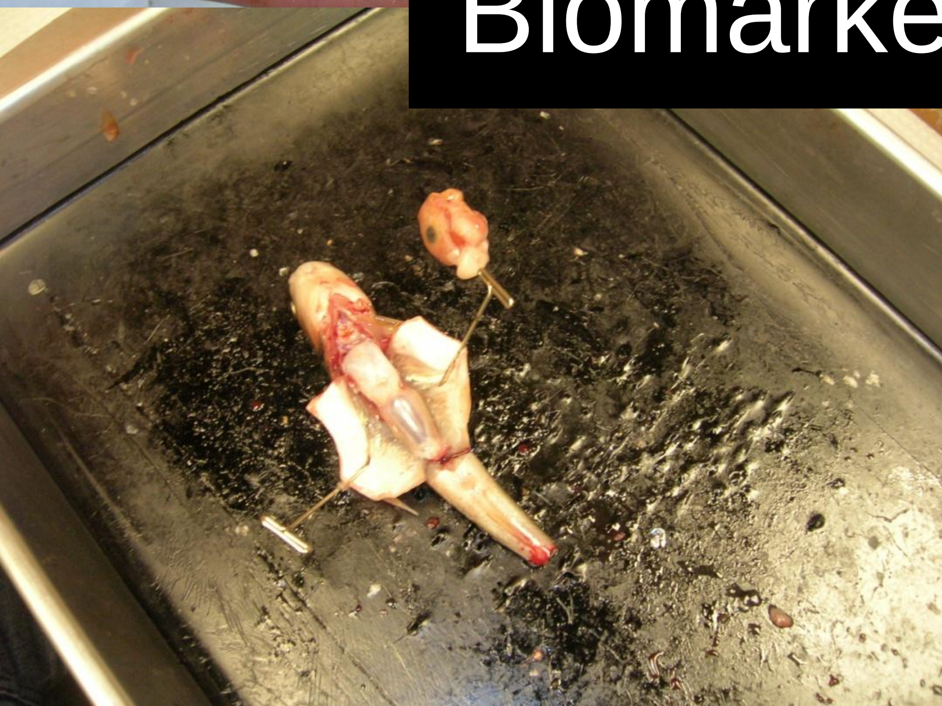
2010 Bioassay Results





- No differences in mortality, hepatosomatic index, gonadosomatic index

Biomarker Studies



Maximum Pesticide and Nutrient Concentrations 2002-2007

	High	Low	Reference
Atrazine (ug/L)	79.7	69.7	1.3
Acetochlor (ug/L)	28.3	12.1	0.2
Simazine (ug/L)	13.3	12.1	0.0
Glyphosate (ug/L)	31.6	6.9	0.0
Nitrate+Nitrite (mg/L)	27.1	24.1	2.8
Ammonia (mg/L)	3.4	1.4	0.4

2004 Biomarker Results

	K	Hepatosomatic Index	Hematocrit	Plasma Vitellogenin
Male – Low	92 a	25 a	62 a	0.10 a
Male – High	93 a	23 a	50 b	6.95 a
Female - Low	98 a	25 a	57 a	1.2 a
Female - High	93 a	31 a	44 b	1.4 a

- Collection of fishes occurred after spring flush of pesticides and nutrients in late June 2004

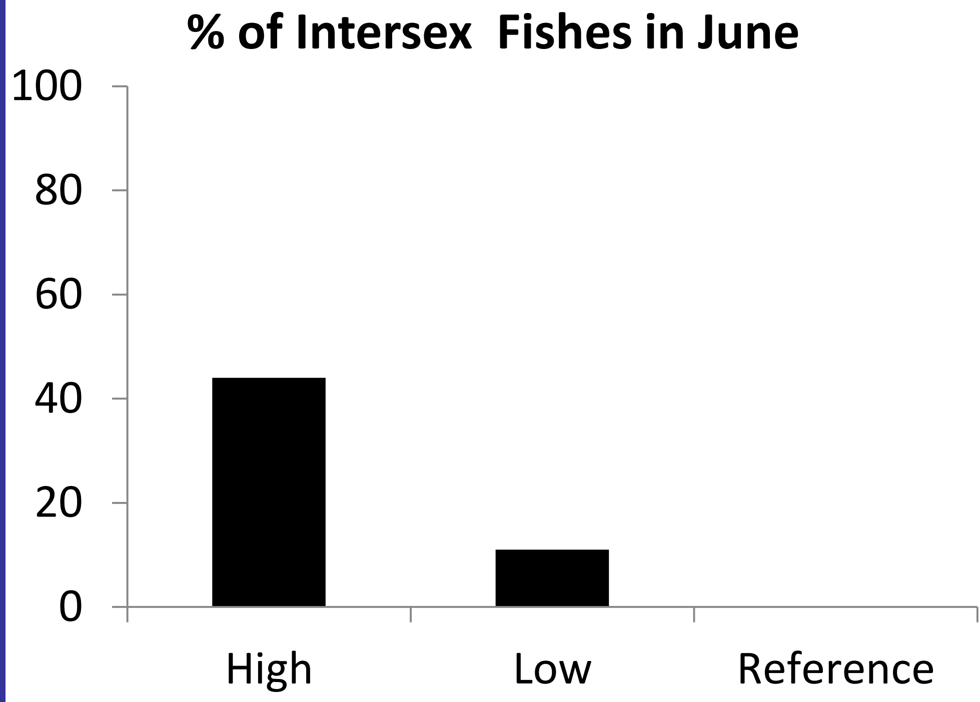
2008 Biomarker Results

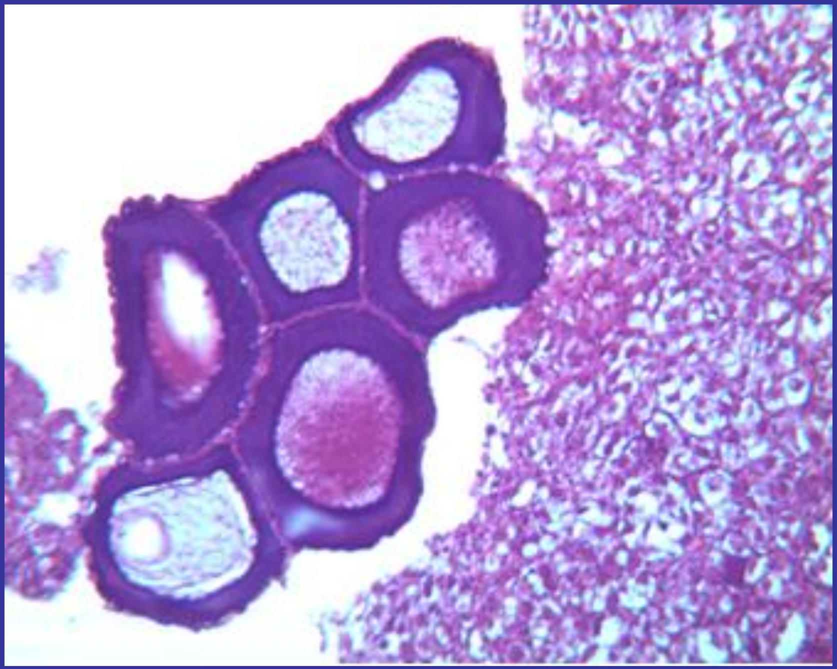
	CYP19 Males	CYP19 Females	VTG Males	VTG Females
High	1.16 a	0.35 b	0.60 a	0.46 a
Low	1.01 a	0.92 a	0.55 a	2.06 a
Reference	1.01 a	1.00 a	1.00 a	1.0 a

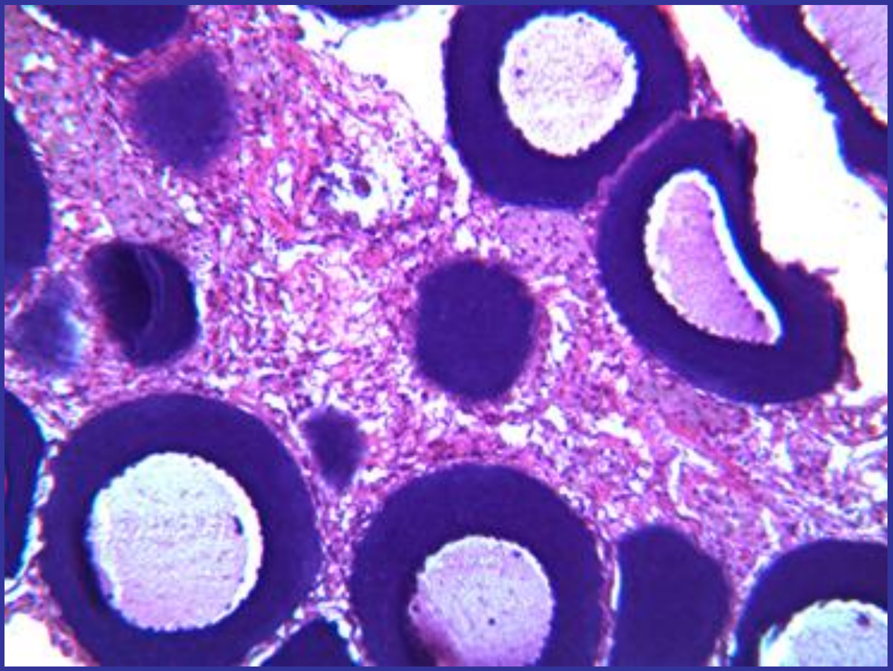
- Use of Quantitative real-time polymerase chain reaction (QPCR) technology to measure genetic expression for gonad aromatase (CYP19) and liver vitellogenin (VTG)

2008 Histology Results

- No abnormalities documented in May sampling
- Five intersex fishes documented in June sampling







2006 to 2009 Biomarker Study

	Allelic Richness	Gene diversity	Inbreeding coefficient
High	5.4 a	0.63 a	0.06 a
Low	5.9 a	0.66 a	0.08 a
Reference	5.2 a	0.64 a	0.02 a

Conclusions

- Fish Community Assessments
  - Fishes most strongly correlated with instream habitat compared to riparian habitat and water chemistry in both CC and UBWC
  - Influence of watershed size similar to instream habitat
  - Changes in hydrology and substrate appear to be the mechanism by which watershed size influences fish community structure
- Bioassays
  - Reduced growth in laboratory reared fathead minnows
- Biomarker Studies
  - Reduced hematocrit, reduced CYP19 gene expression, and increased occurrence of intersex individuals within creek chubs from streams with greater levels of agricultural contaminants

Implications for Stream Restoration

- Results provide predictions on what types of practices will be most effective in restoring fish biodiversity in channelized agricultural headwater streams in the Midwest
  - Most effective practices will be those that lead to improvements in instream habitat quality
  - Practices that reduce nutrient and pesticide loading without altering physical habitat not likely to improve fish biodiversity

Implications for Stream Restoration

- Appears to be a dichotomy in conservation and restoration approaches towards agricultural streams in the Midwest
  - Agricultural Community – Focus on watershed and upland practices for water quality improvement
  - Stream Restoration Community – Focus on riparian and instream habitat to benefit the biota
  - Our results suggest that restoration approaches in channelized agricultural headwater streams that combine these two approaches are likely to have the greatest ecological benefits

Acknowledgements

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