Development of Ecological Flow Indicators for Ohio Streams and Rivers

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Could We Use Ohio Biological Data to Predict Adverse Ecological Impacts from Flow Alterations?

- Ohio has 30 years of biological (fish & invertebrate data) data collected in a consistent and robust way
- This biological data has been shown to respond to a wide range of stressors that include not only water quality, but stressors such as habitat, nutrients, sediments and flow changes
- Tiered goals have been set for waters that recognize that ecological sensitivity to stressor varies across the state – ***not*** a one size fits all approach that provides higher protections for better, more diverse, and sensitive streams

Different Effects from Low vs. High Flow Alterations?

- Many possible changes from “natural” flow regime can influence aquatic life, but two major categories of impact include:
  - Too little flow (e.g., from water withdrawals, reduction in base flows from agricultural drainage, etc.)
  - Too much flow (e.g., increased flashiness from increasing impervious surface, stormwater)
- Mode of effect may differ between these impacts and thus biological responses may differ

Reduction in Base Flows

- Reduction in base flows can have important effects where water withdrawals are large and natural flows are low (e.g., small streams in August-September in Ohio)
- How do we predict the influence of reducing base flow to design protective ecological flows during typical low flow “bottlenecks”?
- What are the ecological benefits that such base flows provide?

Stream Flow is Really a Measure of Available Habitat for Aquatic Life

- Stream habitat types or “niches” generally increase with stream size and flow; withdrawal of flow could limit the amount of habitat
- Fish are adapted through morphology and behavior to specific habitat types
  - Bottom, mid-water, top-water
  - Slow, moderate, fast, swift flow
  - Soft, fines, gravels, cobbles, boulders
  - Structures such as undercuts, aquatic plants, rootwads, oxbows, etc.

Redside Dace, Top

Striped Shiner, Midwater

Variegate Darter, Bottom

Fish Population Biology and Species Distribution with Stream Size

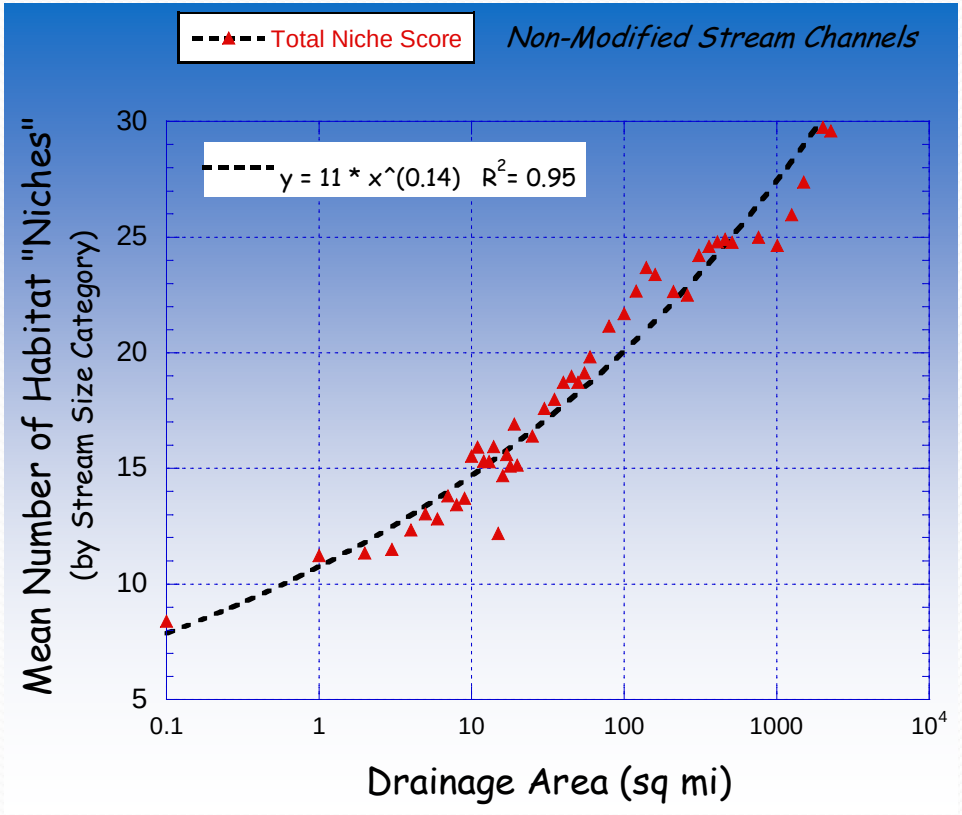
- Development of Fish IBIs recognized that expected fish species richness is dependent on stream size, typically measured using drainage area; most richness metrics are calibrated to such a variable.
- Smaller streams may contain fewer different habitat niches that might partly explain why species richness increases as stream size (base flow) increases.
- How can we quantify this or measure whether increasing habitat complexity can contribute to this observation?

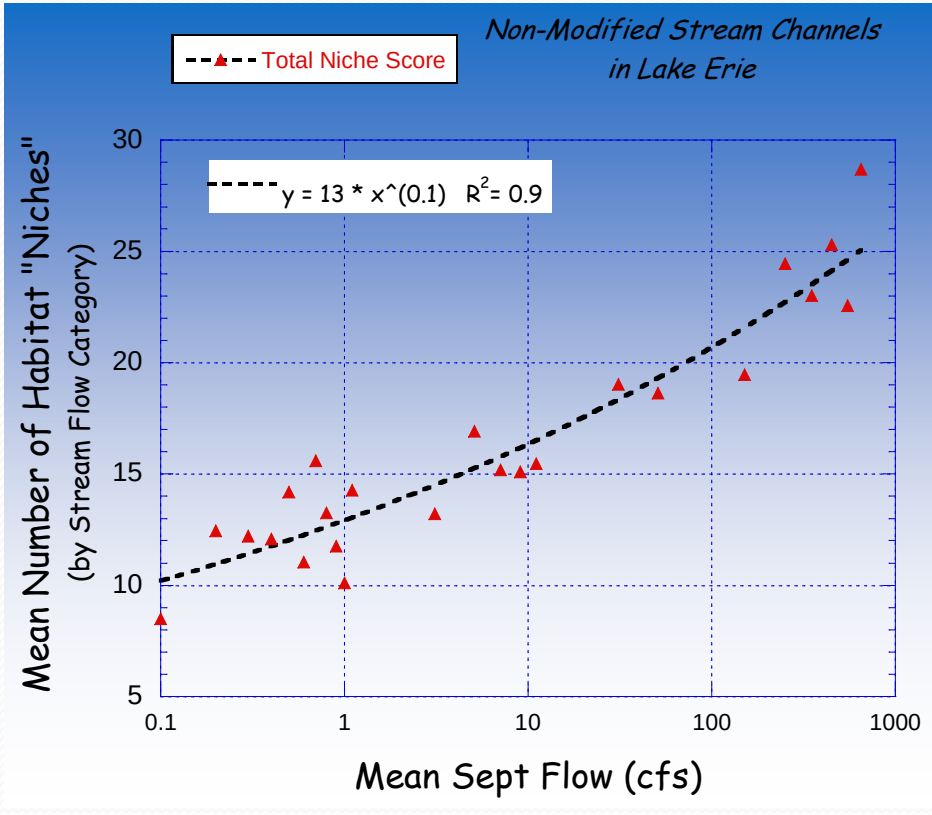
We Calculated "Habitat Niches" Using the QHEI

Table 1. Summary of general process to classify number of niches at sites with natural channels in Ohio.

Total Niches	Pool Niches	Riffle Niches	Current Niches	Structure Niches
Score 0-63	Increase with depth and with increase depth of riffle and run connecting features (Score 0-15)	Increase with riffle depth and increasing coarseness of substrates (Score 0-15)	Increase with diversity and velocity of flows (0-15)	Increase with variety and amount of cover types (Score 0-17)

Data from Statewide and Lake Erie Drainages





Example Streams with Drainage Areas and Mean Sept Flows (cfs)

Data for Linking Flow Statistics to Sensitive Species

- USGS has developed methods for estimating flow data for any free-flowing stream and stream site in Ohio (StreamStats)
  - Simple stream size model
  - More complex tool that includes GIS information on land use, stream flow variability, precipitation, slope, etc.
- We chose the mean September flow statistic as our best available indicator of low flow conditions in Ohio.

Needed to Select Ecological Indicators Sensitive to Flow

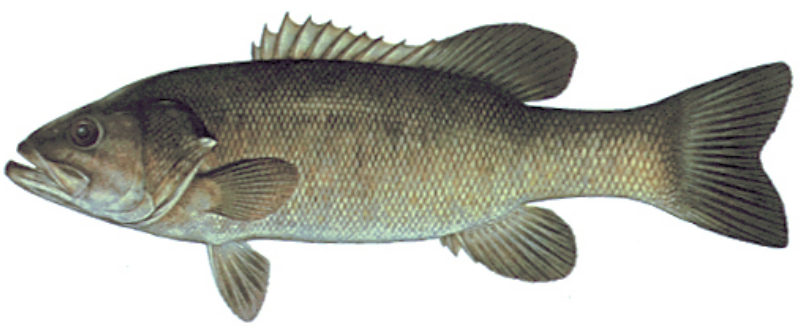
- Ohio is data rich
- Ohio has standardized lists of fish and invertebrates that are sensitive to flow, among other stressors

Smallmouth Bass

Stoneflies

Streams with High Numbers of Sensitive Species have:

- High recreational value
- Larger populations of sport fishes
- High aesthetic value
- Meet standardized biological goals for Ohio streams



The Biological Condition Gradient: Biological Response to Increasing Levels of Stress

Levels of Biological Condition

Natural structural, functional, and taxonomic integrity is preserved.

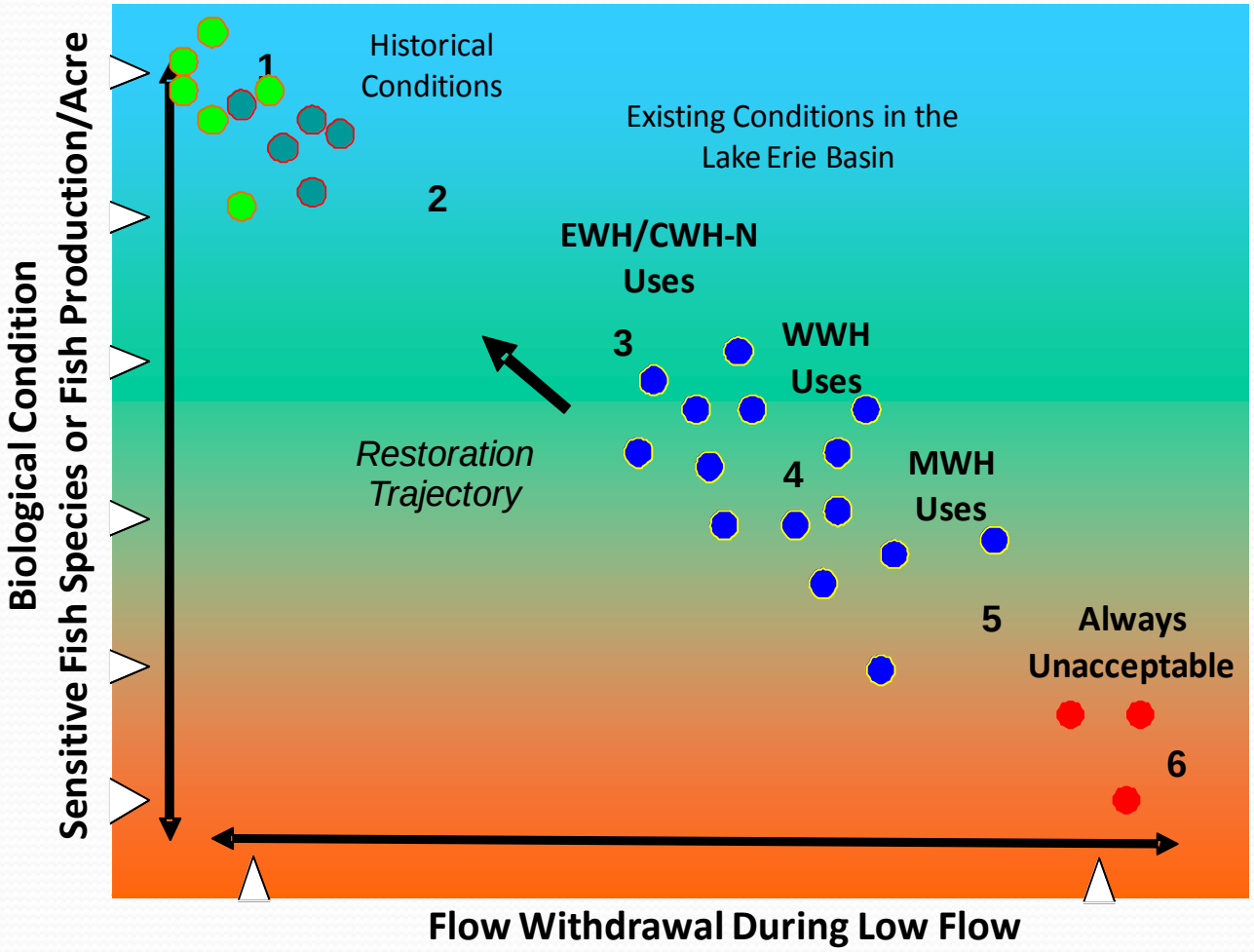
Structure & function similar to natural community with some additional taxa & biomass; ecosystem level functions are fully maintained.

Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained.

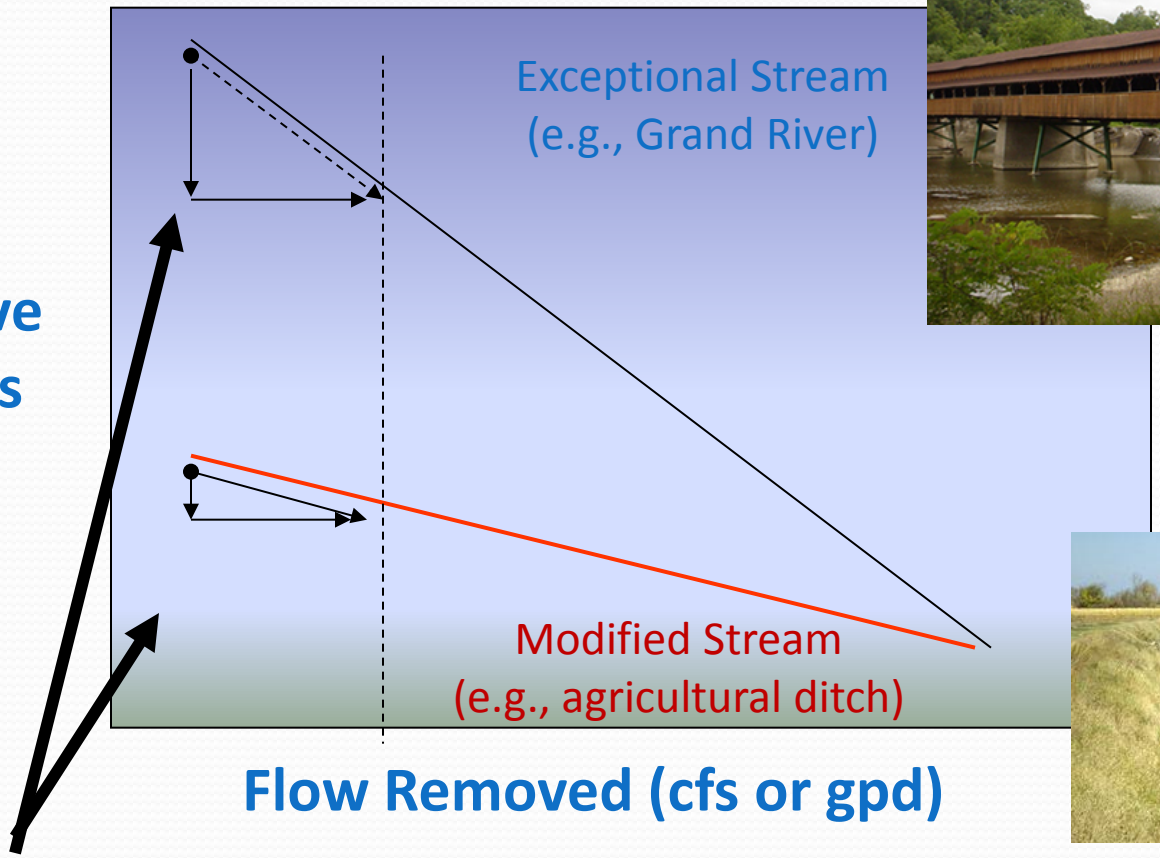
Moderate changes in structure due to replacement of sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained.

Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy.

Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.

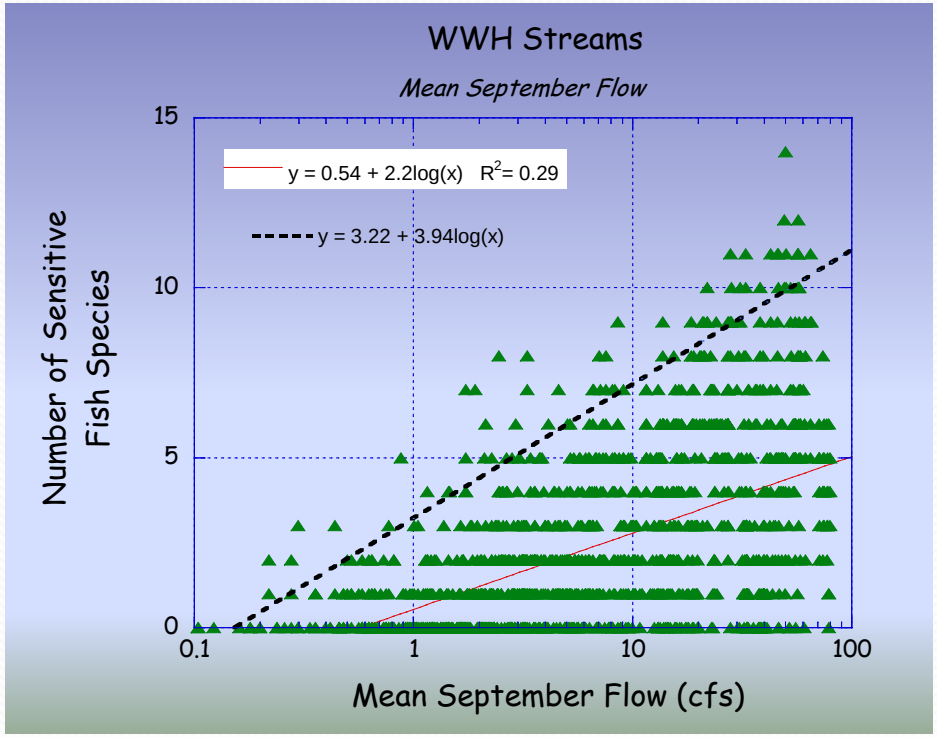


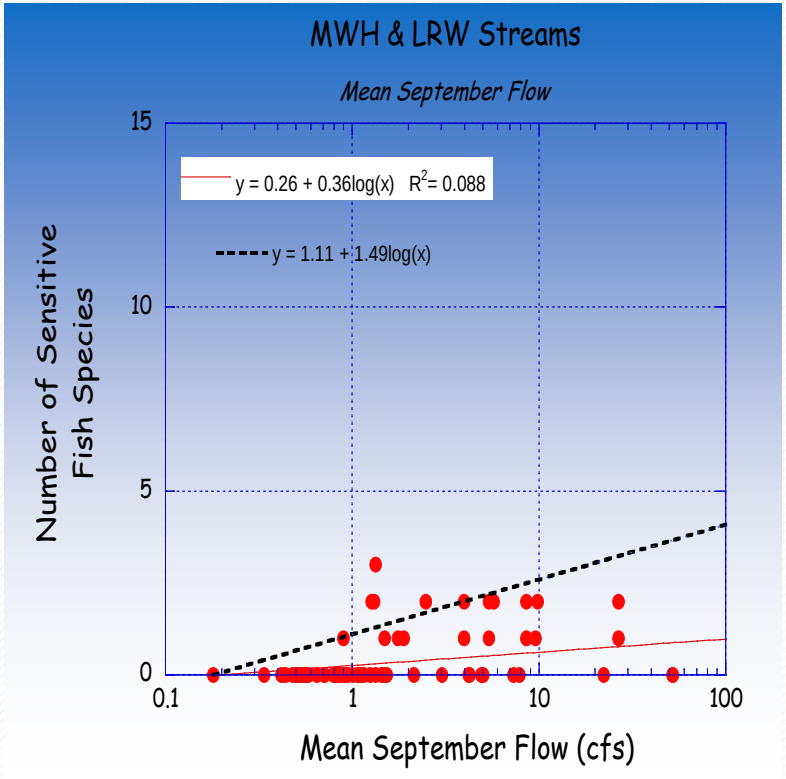
Withdrawal of Flow May Reduce Number of Sensitive Species



Reducing flow reduces number of species site can support, but this varies with type and use of stream

Sensitive Fish Species in Lake Erie Drainage by Aquatic Life Use





Ohio has existing tiered aquatic life uses: Exceptional, Warmwater, Modified and Limited

Used Quantile Regression to Define Thresholds (USGS Blossom Software)

Use Stream Flow x Sensitive Species Relationships to Create Decision Rules

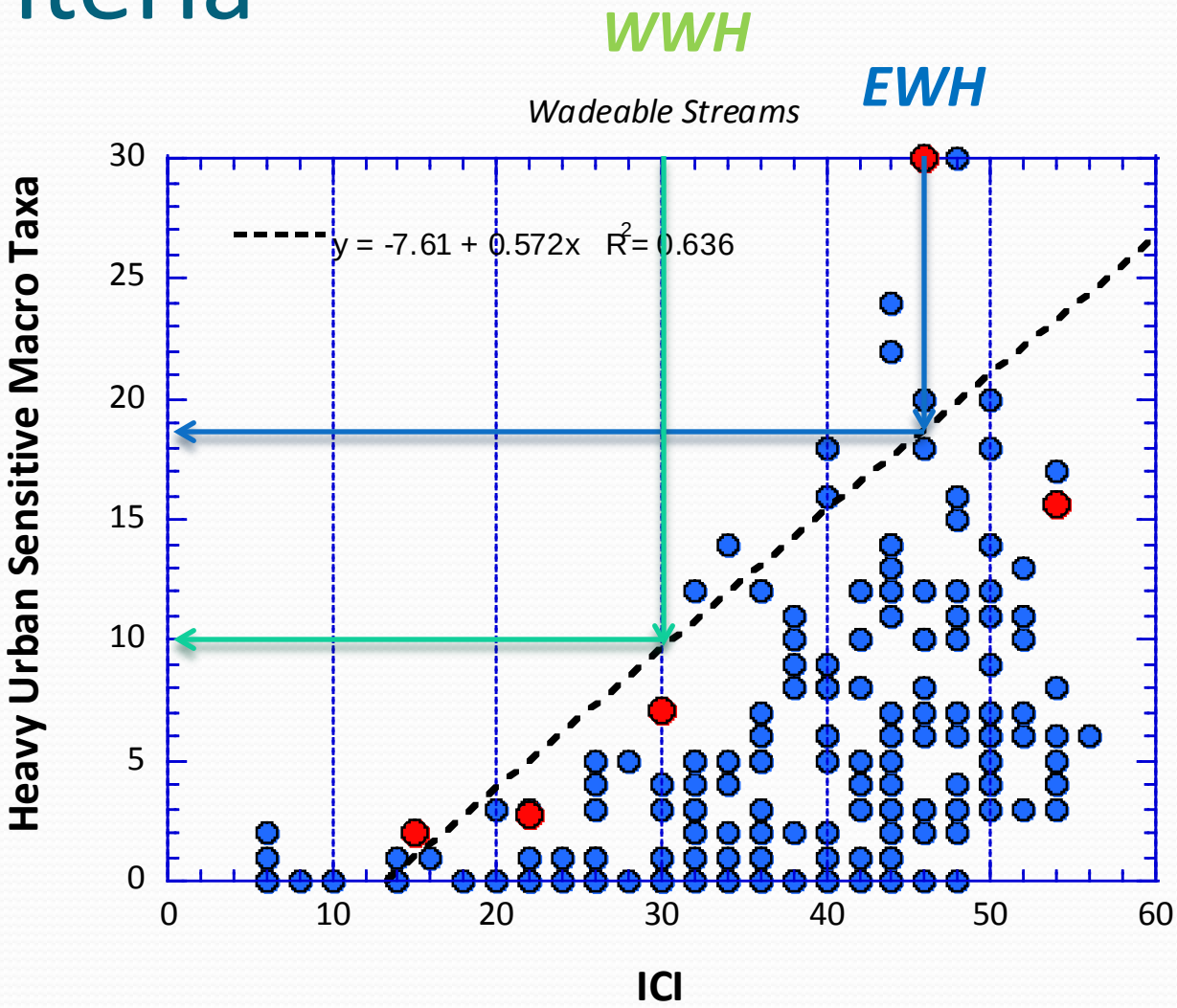
- Varies with Stream Size (Important), Aquatic Life Use and Ecoregion
- Used Mean September Flow, but added a safety factor tied to $Q_{7,10}$ flow and Aquatic Life Use
- Focus on protecting best resources
- Alternate proposals to set single thresholds not protective of smaller streams
- Would apply now to direct withdrawals, but eventually a groundwater screening tool can be developed (e.g., Michigan groundwater tool).

Table 10. Number/percent of Lake Erie stream sites (wadeable streams) by aquatic life use that would be affected biologically by specific flow withdrawal thresholds from 100K (100,000) gallons/day (GPD) to 2,000K (2,000,000) GPD.												
Aquatic Life Use	Stream Sizes	Flow Withdrawal Threshold Level										
		100K GPD		250K GPD		500K GPD		1,000K GPD		2,000K GPD		Tot N
		N	%	N	%	N	%	N	%	N	%	
EWH & CWH	Headwater <= 20 sq mi	53	100	53	100	53	100	53	100	53	100	53
	Small wadeable >20-100 sq mi	9	9.7	88	94.6	93	100	93	100	93	100	93
	Large wadeable >100-300 SQ	0	0	0	0	21	44.7	47	100	47	100	47
WWH	Headwater <= 20 sq mi	749	71.9	965	92.7	1042	100	1042	100	1042	100	1042
	Small wadeable >20-100 sq mi	0	0	130	13.7	381	40.1	650	68.4	880	92.5	951
	Large wadeable >100-300 SQ	0	0	0	0	0	0	0	0	75	10.8	697
MWH	Headwater <= 20 sq mi	15	15.8	56	59.0	80	84.2	95	100	95	100	95
	Small wadeable >20-100 sq mi	0	0	0	0	0	0	9	11.4	51	64.6	79
	Large wadeable >100-300 SQ	0	0	0	0	0	0	0	0	0	0	13
% Impacted Sites Color Code:				0--20		21-40		41-50		> 50		

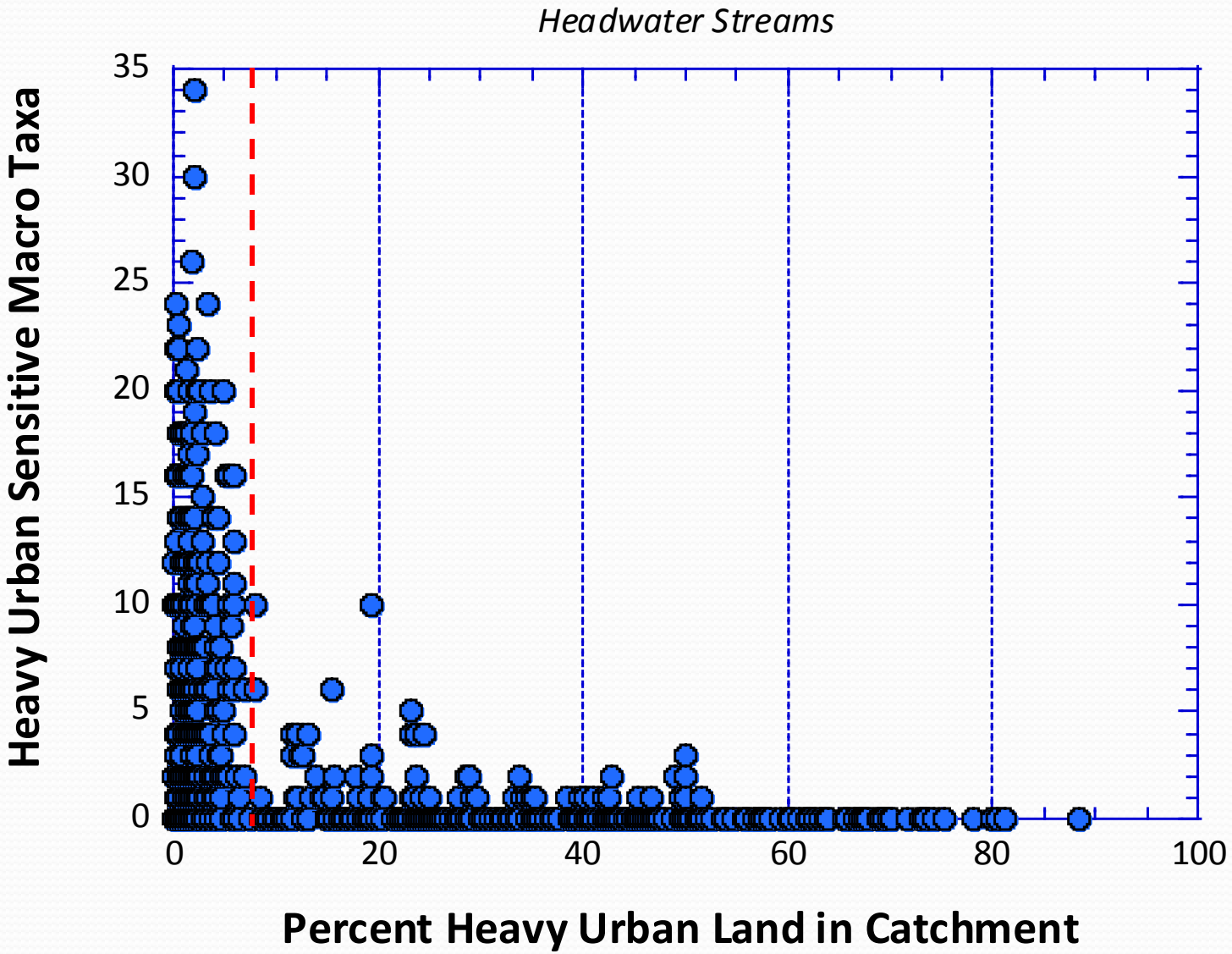
High Flow Impacts

- Flashiness related impacts are widespread in US
  - “Urban Stream Syndrome”
- For SW Ohio we used weighted means to generate lists of taxa sensitive to various impacts (e.g., chloride, urban land uses, etc.)
- We then related the numbers of sensitive taxa back to the ICI or IBI to identify values consistent with biocriteria benchmarks
- Altered flows can be highly correlated with habitat disturbances (stream entrenchment) and polluted runoff (e.g. chloride, nutrients, PAHs, sedimentation, etc.)

Sensitive Macro Taxa Associated w/ Biocriteria



Data from SW Ohio (Cincinnati)



Conclusions:

- Flow regime is a major limiting factor, directly and indirectly, to aquatic life condition in Ohio
  - Flow Withdrawal – Current regulatory approach in Ohio does not consider data shown here at present; current approach has 90 or 45 day averaging periods that might not be protective of high quality smaller streams
  - Flow Flashiness – A more widespread problem in Ohio
    - Stormwater, including flow alteration responsible for widespread aquatic life impairment in Ohio streams and rivers
    - Altered flow regimes and loss of ***natural*** stream and flood-prone habitats likely contribute to nutrient and algae problems

Conclusions, continued:

- USGS StreamStats provided invaluable data to water withdrawal analyses (e.g., mean Sep low flow estimates at ungaged sites)
- Robust biological data allows refine exploration of the influence of various flow statistics
- Flow model that provides daily or better flow statistics at ungaged stream sites, including small streams would provide improvement over the use of surrogate measures (e.g., impervious surface) to statistically discriminate among multiple stressor that may limit aquatic life.