Ecological Low Flow Protection Process for Ohio Streams and Rivers of the Lake Erie Basin

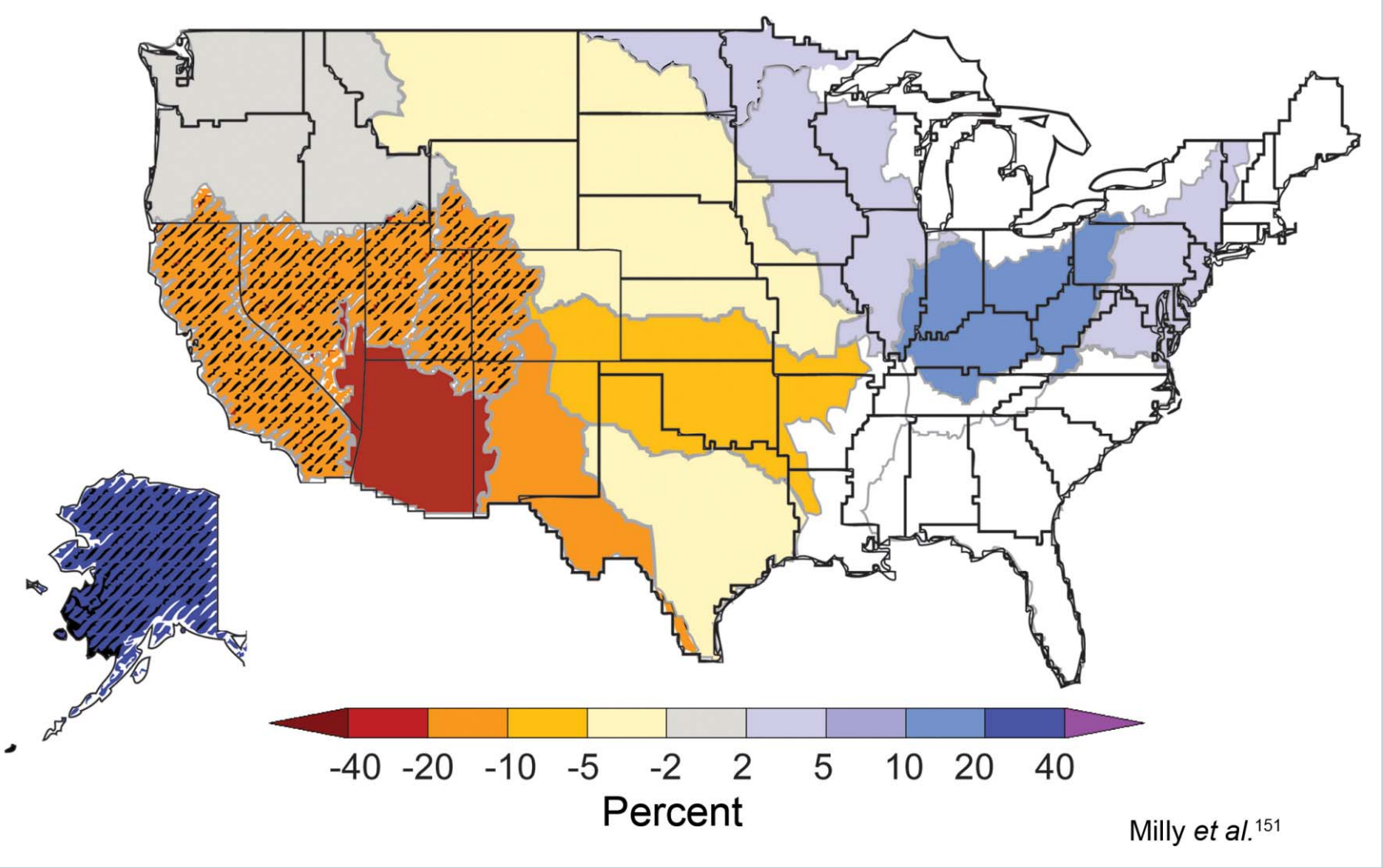
MIDWEST CLIMATE CHANGE WORKSHOP

OCTOBER 26-27, 2010

USEPA – REGION 5 OFFICE

CHICAGO, IL

Projected Impacts on Runoff

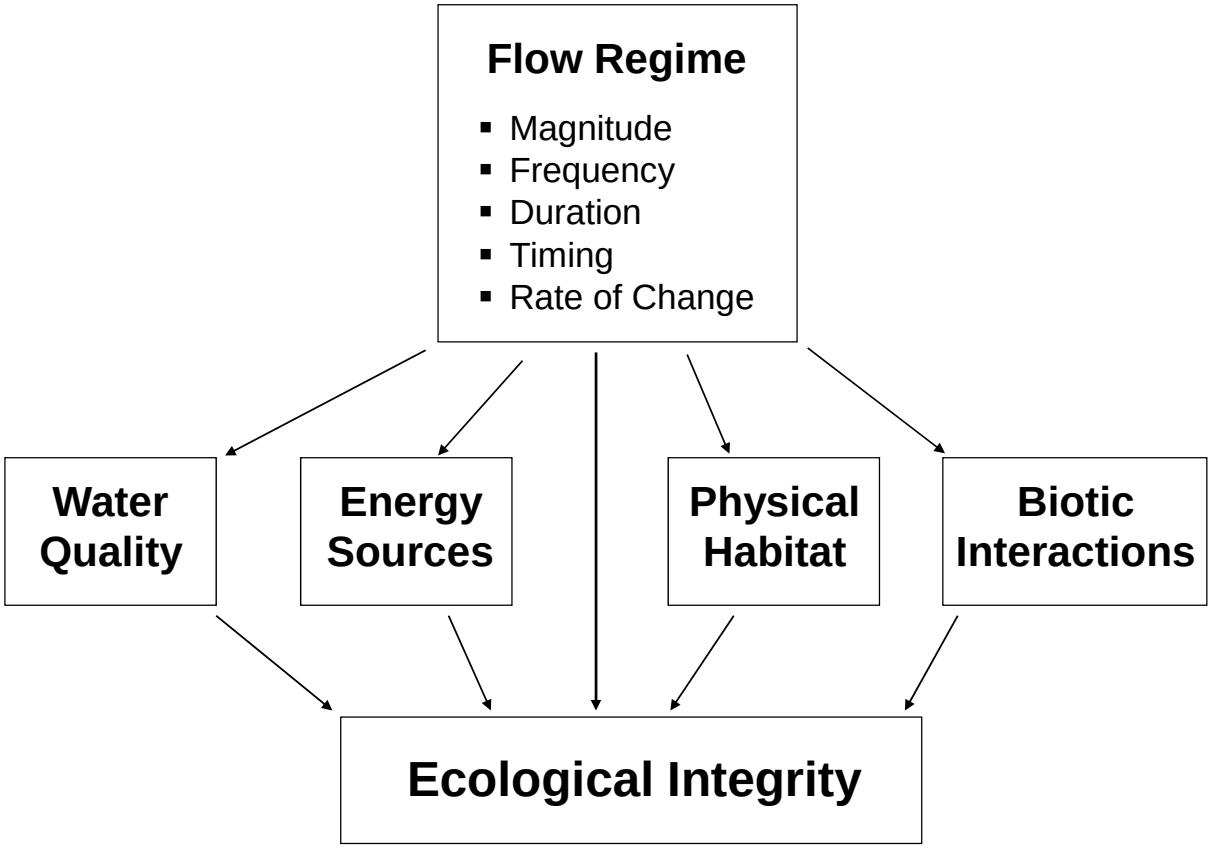


Midwest: Climate Change Projected

- The observed patterns of temperature increases and precipitation changes are projected to continue
- Increasing precipitation in winter and spring and heavy downpours is expected to lead to more frequent flooding
- Heavy downpours can overload drainage systems and water treatment facilities
- In summer, with increasing evaporation and longer periods between rainfalls, the likelihood of drought will increase and water levels in rivers and wetlands are likely to decline

Karl et al. 2009

Changes to Flow Regime Due to Climate Change

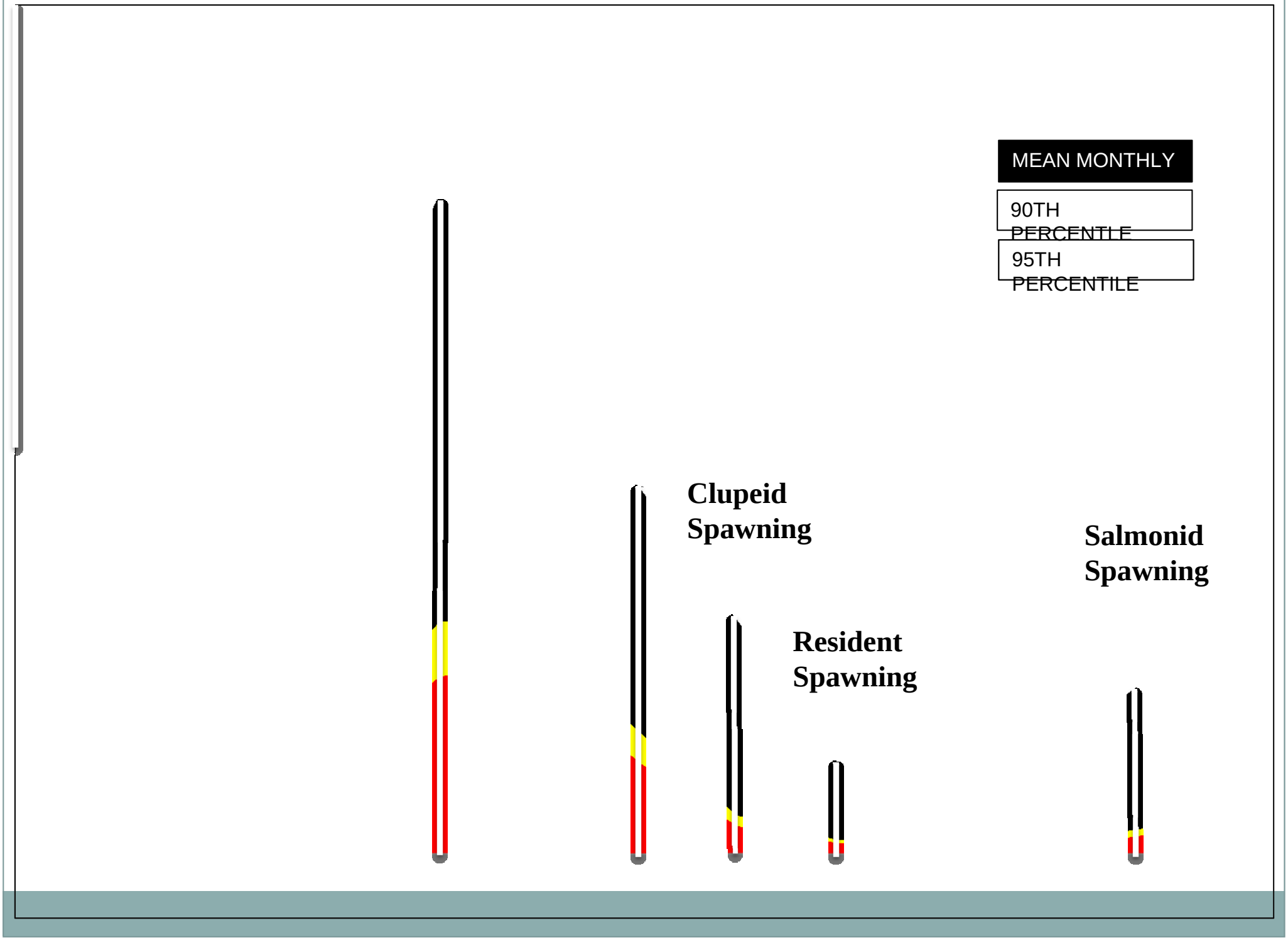


*Ecological Limits of Hydrologic Alteration - **ELOHA***

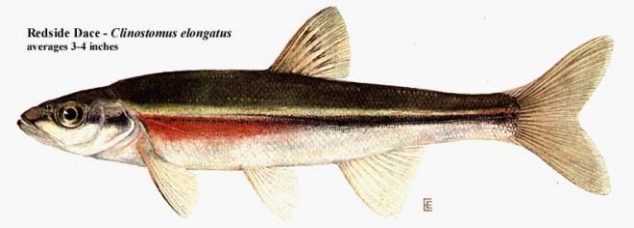
- A scientific approach for setting environmental flow standards over geographic areas as large as a state or country
- ELOHA builds upon the wealth of knowledge gained from site-specific approaches
- Compared to river-by-river approaches, ELOHA is highly cost effective and provides water managers with the ability to protect environmental flows throughout their jurisdictions
- ELOHA will accelerate the protection of environmental flows

Environmental Flows

- Important to understand for climate change implications and related to increase consumptive pressure


MEAN MONTHLY
90TH PERCENTILE
95TH PERCENTILE
Clupeid Spawning
Resident Spawning
Salmonid Spawning

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



Redside Dace, Top

- 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.

Striped Shiner, Midwater

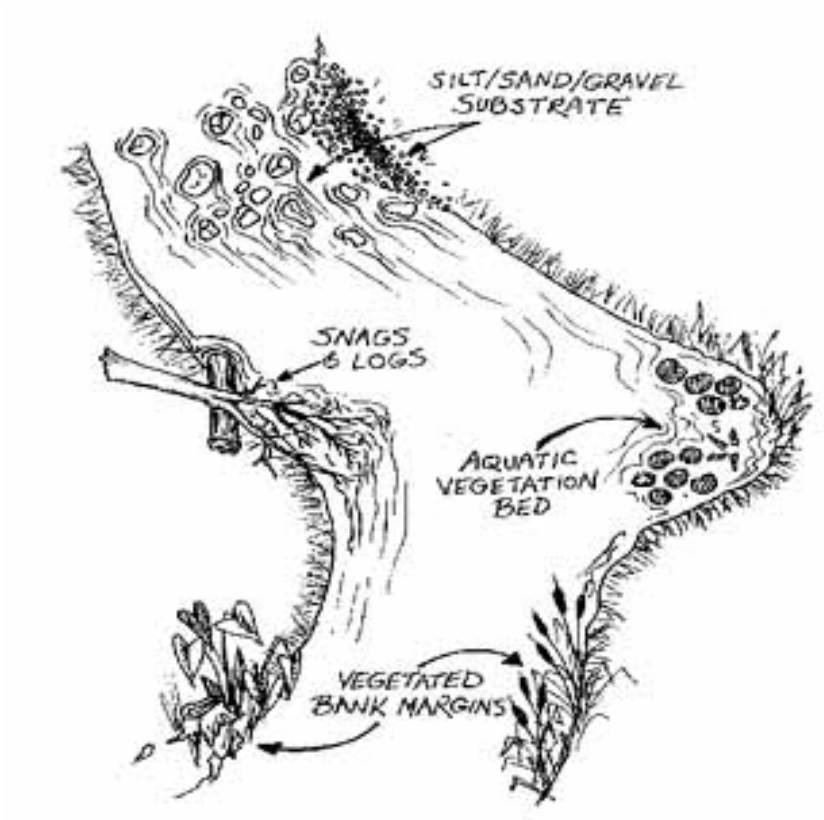
Variegate Darter, Bottom

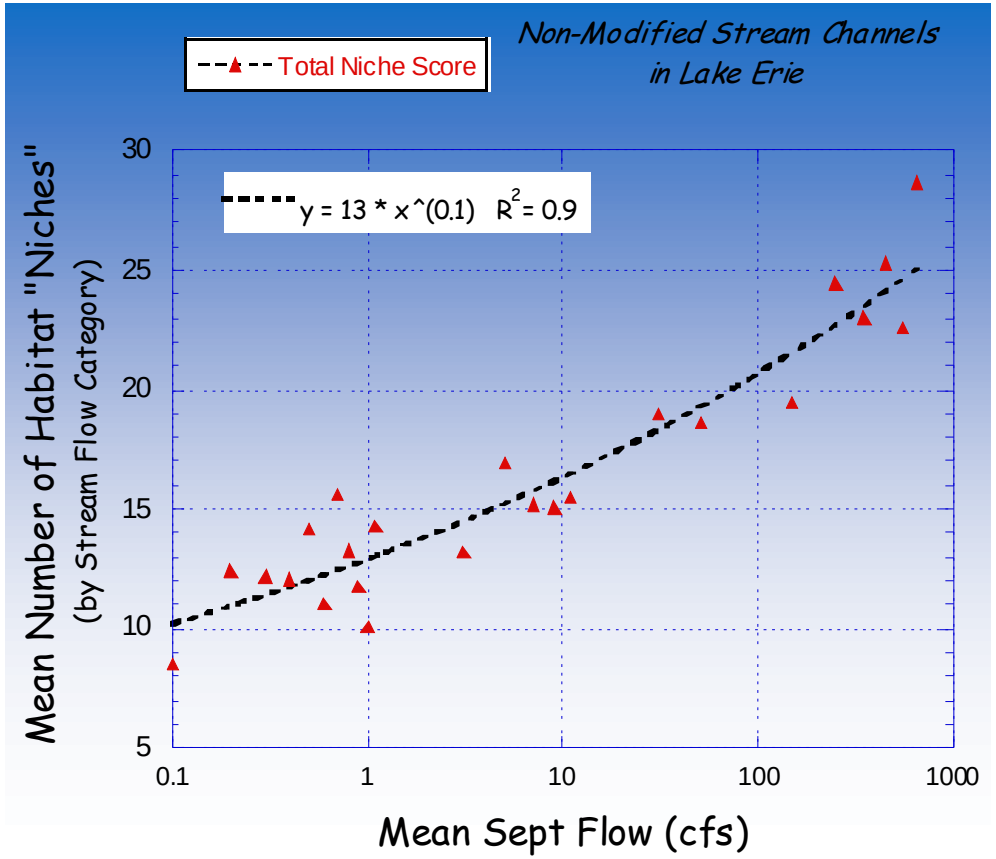
How We Calculated "Habitat Niches" Using QHEI Habitat Index

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)

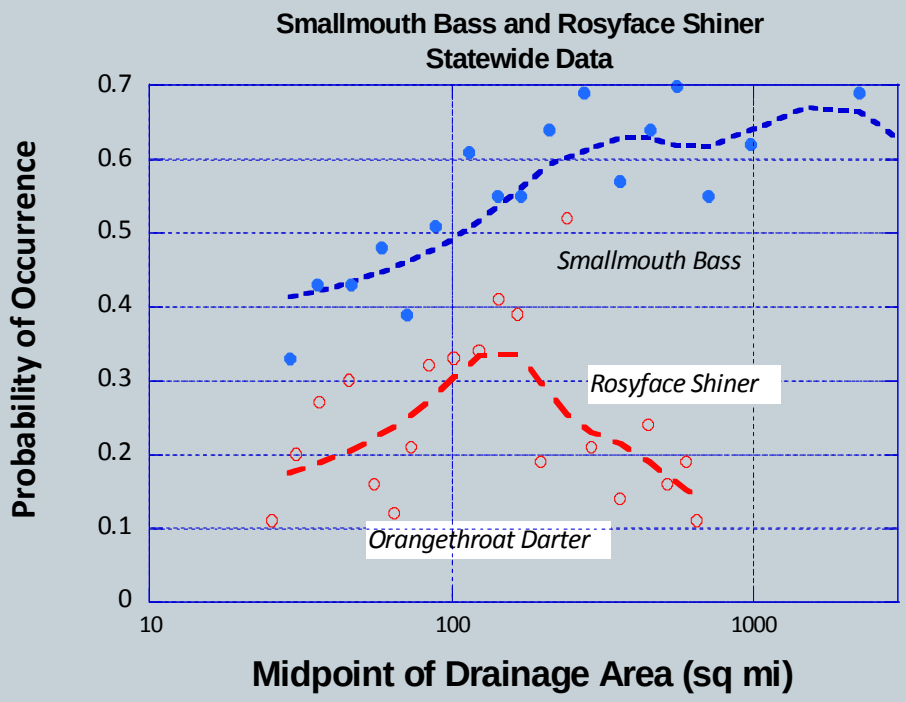
Flow as Habitat

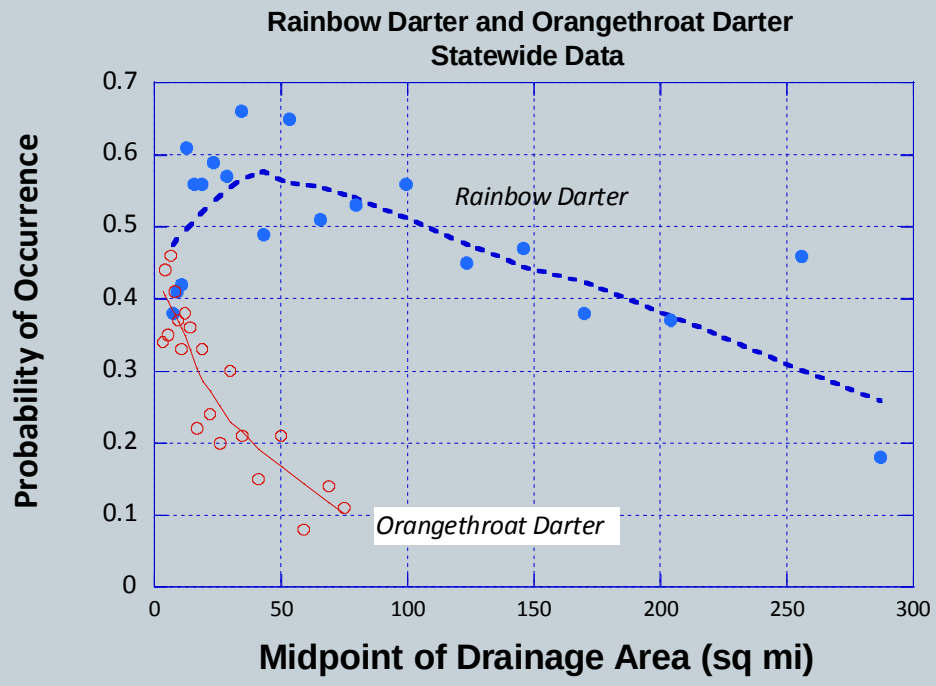




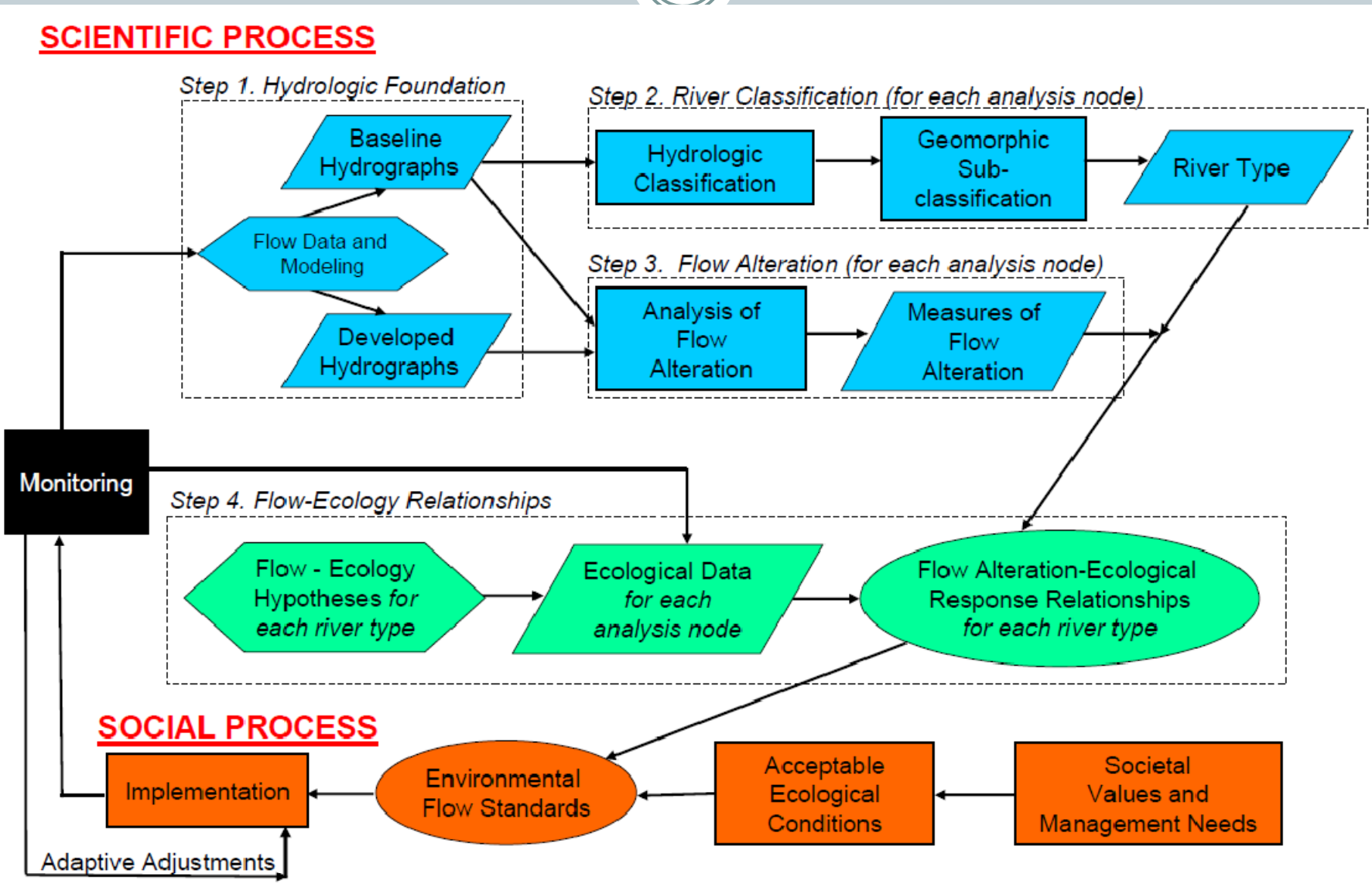
Change in Base Flow Changes Number of Habitat Niches

- Different species adapted to different stream sizes = flow conditions
- Change flow, change species probability of occurrence





ELOHA – Ecological Limitations of Flow



Base Flow in Great Lakes

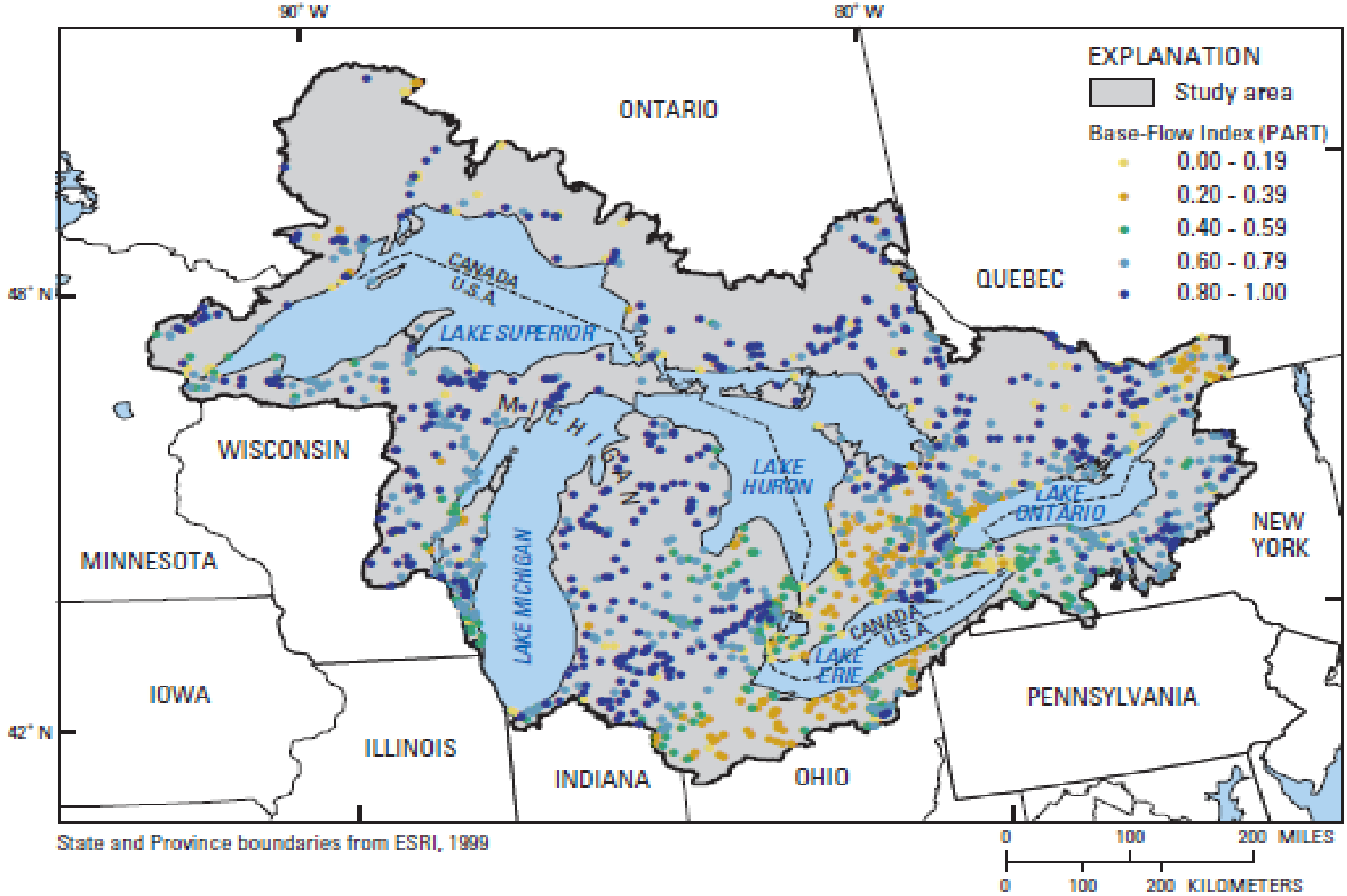
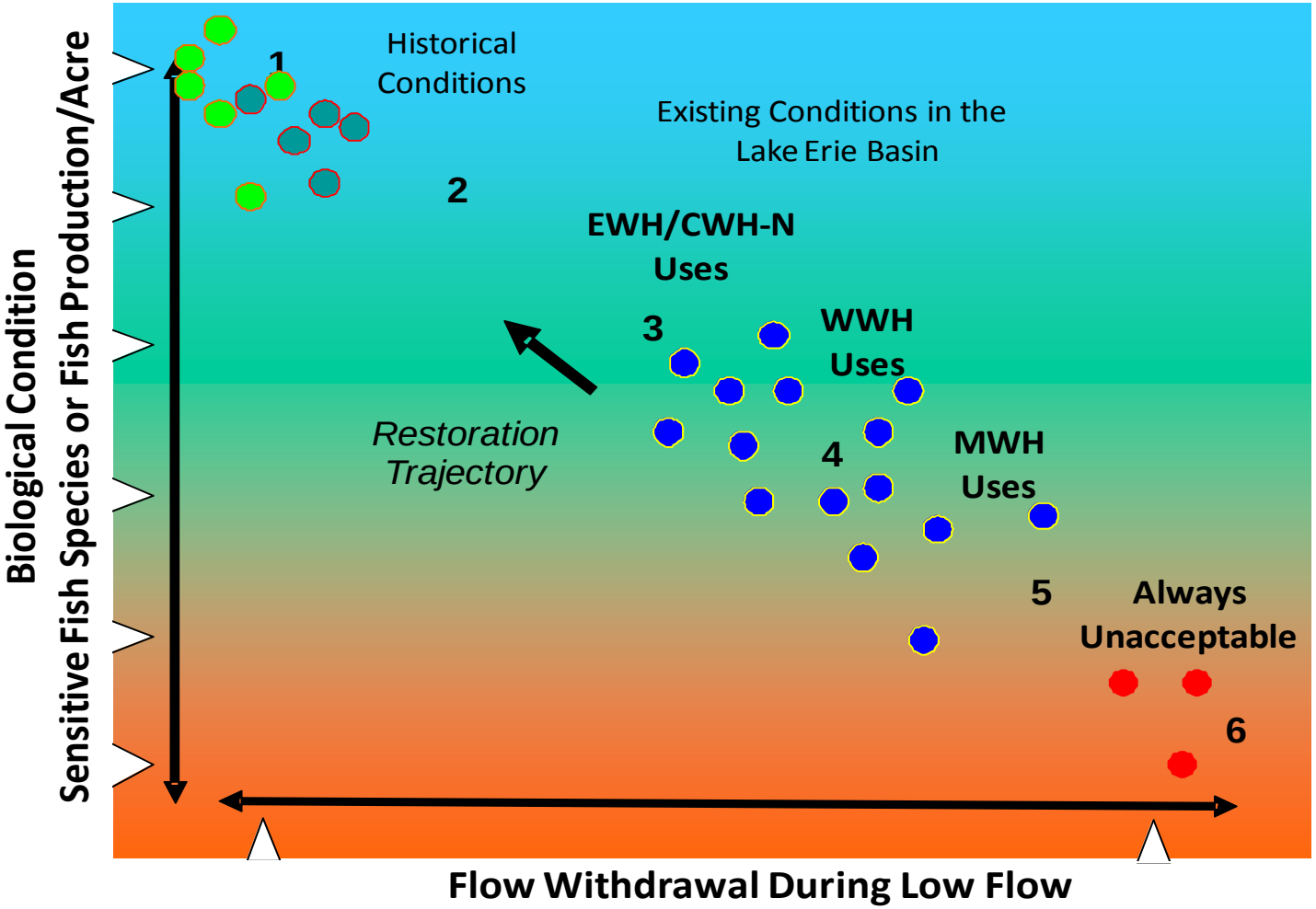


Figure 5. Results of base-flow separation using PART for streamflow records at streamflow-gaging stations within the study area.

Base Flow as Stressor

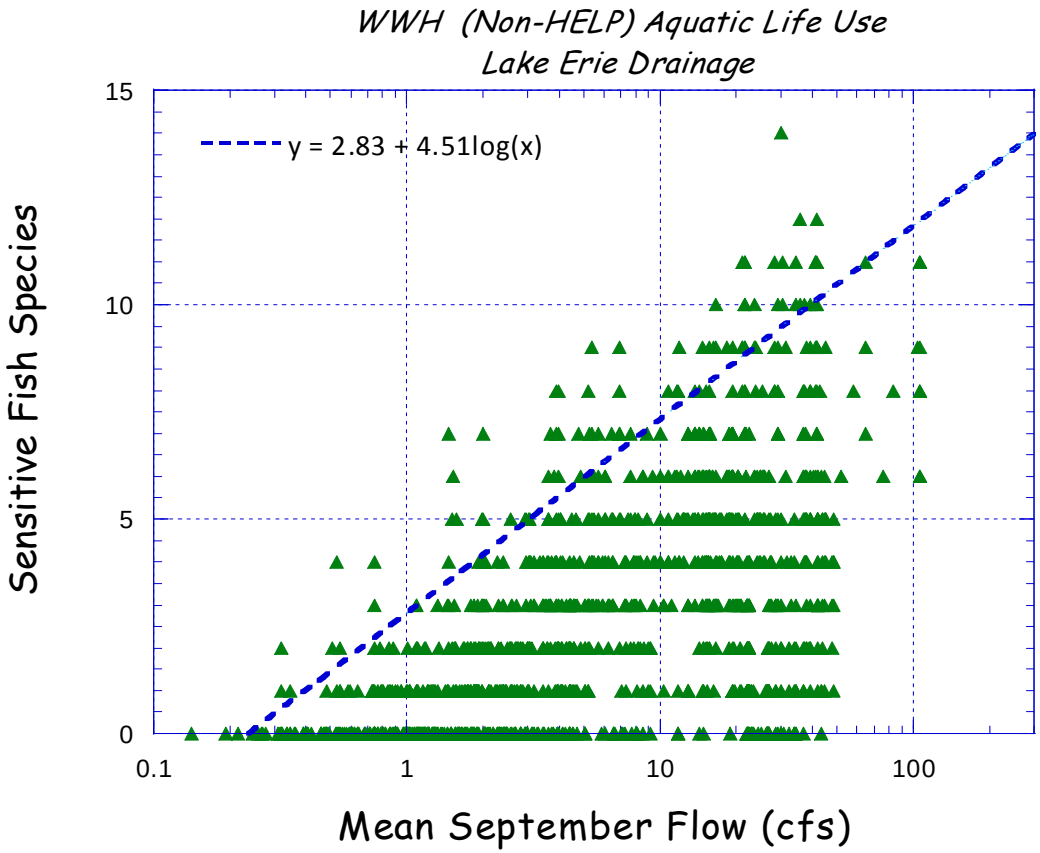


Used Sensitive Species at Key Indicator for Base Flow Withdrawal

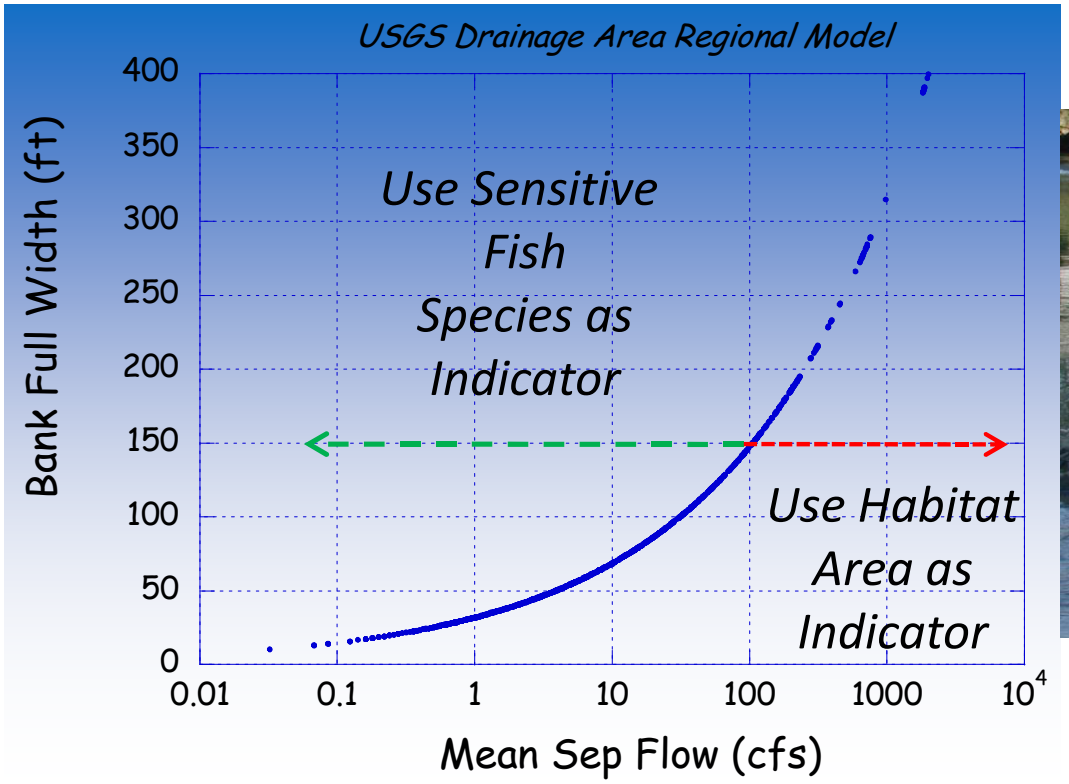
Table 11. Fluvial Make-up of Sensitive Fish Species metric

Category	# (%)
Fluvial Specialists	38 (60.3)
Fluvial Dependents	18 (28.6)
Flow Generalist	7 (11.1)

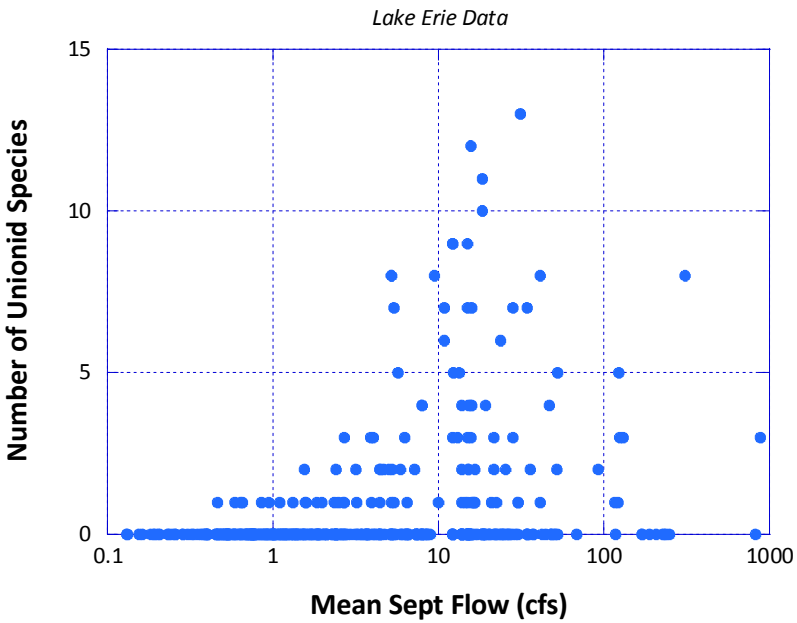
Strong Threshold Relationship Between Base Flow and Sensitive Species

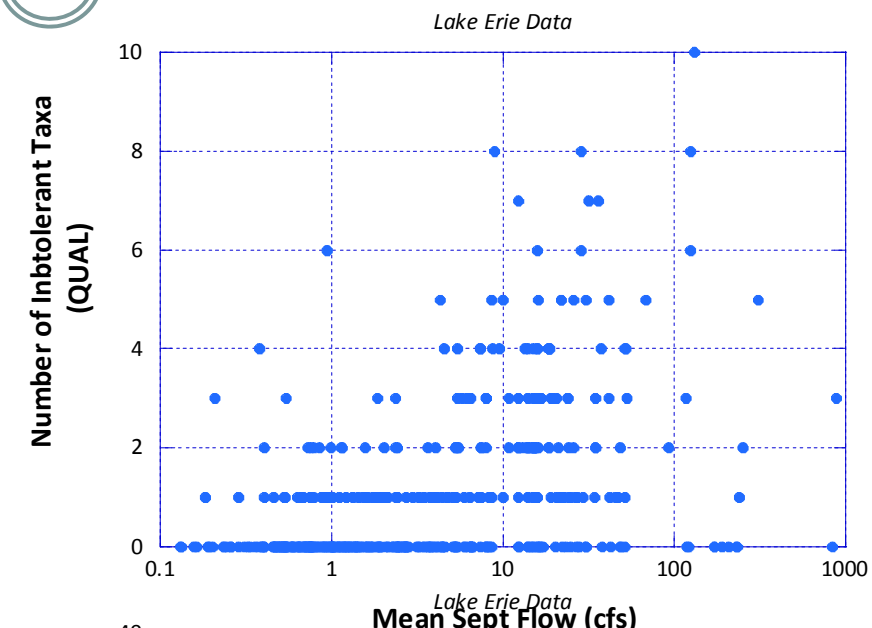


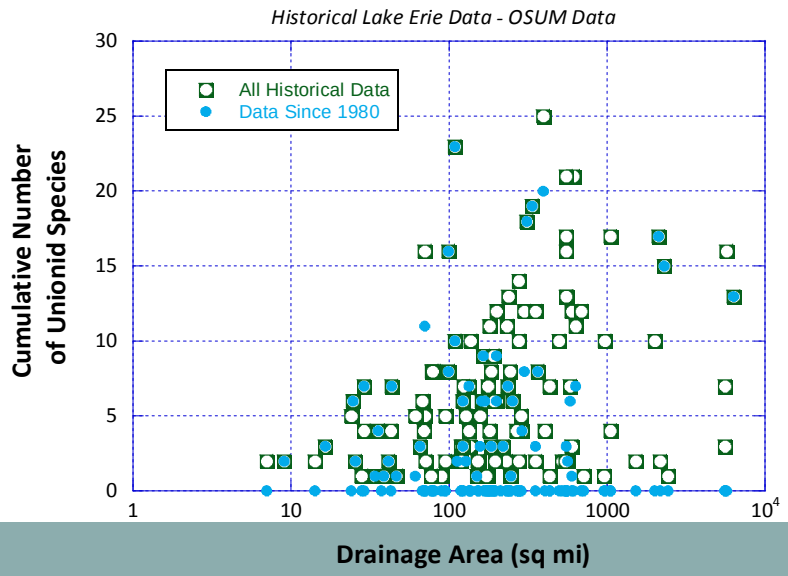
In Larger Streams Sensitive Species per Sample Plateaus, But Continue Protection

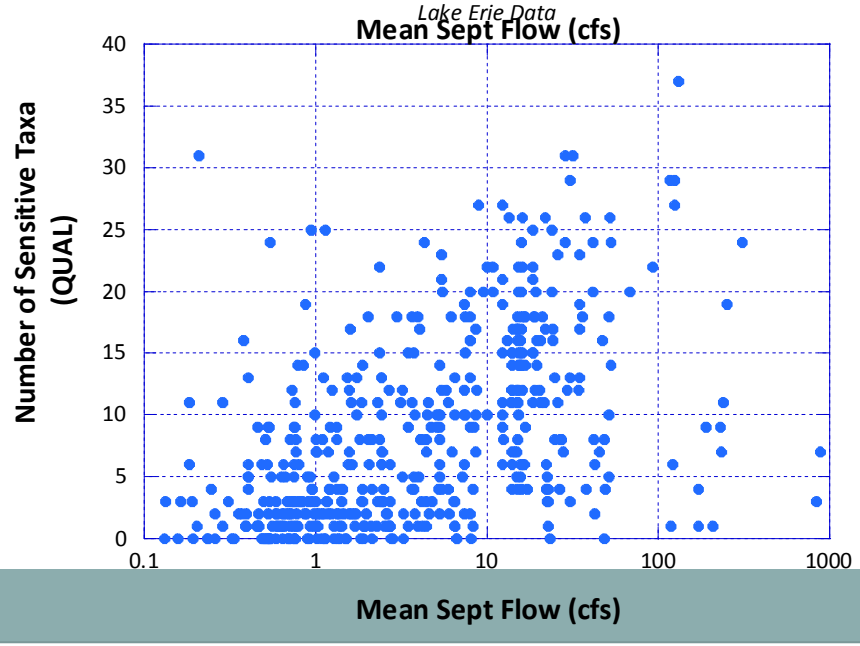


Invertebrates and Mussels Show Similar Relationship

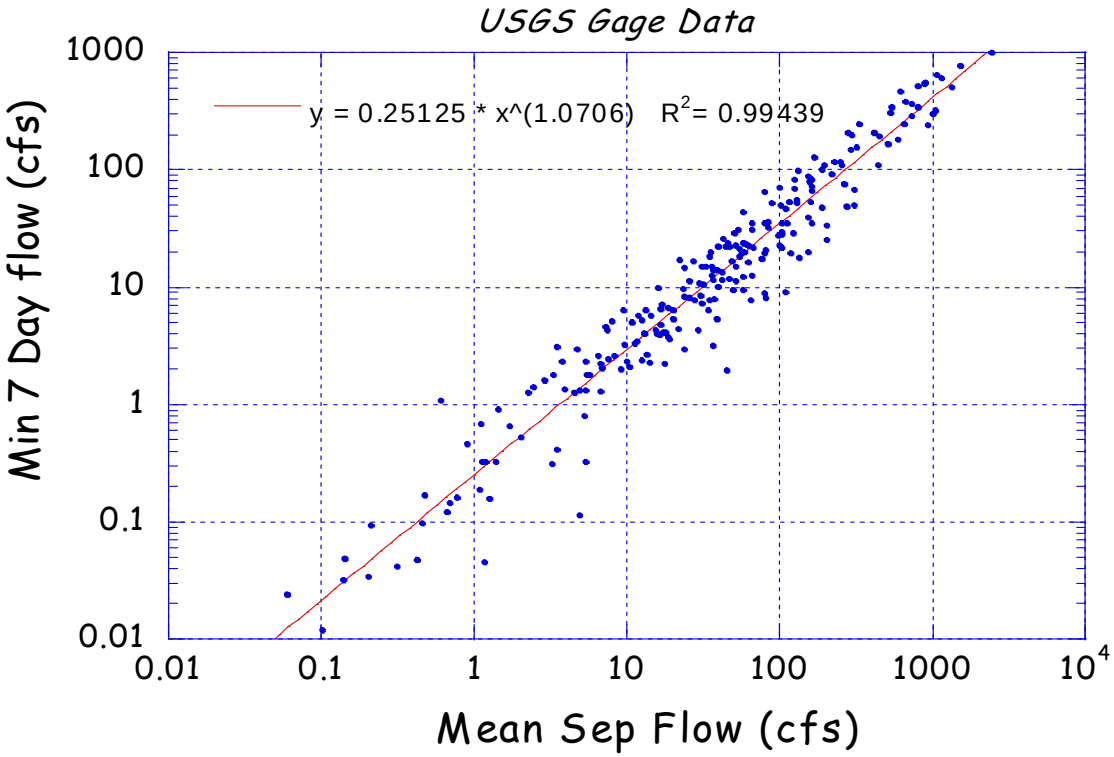




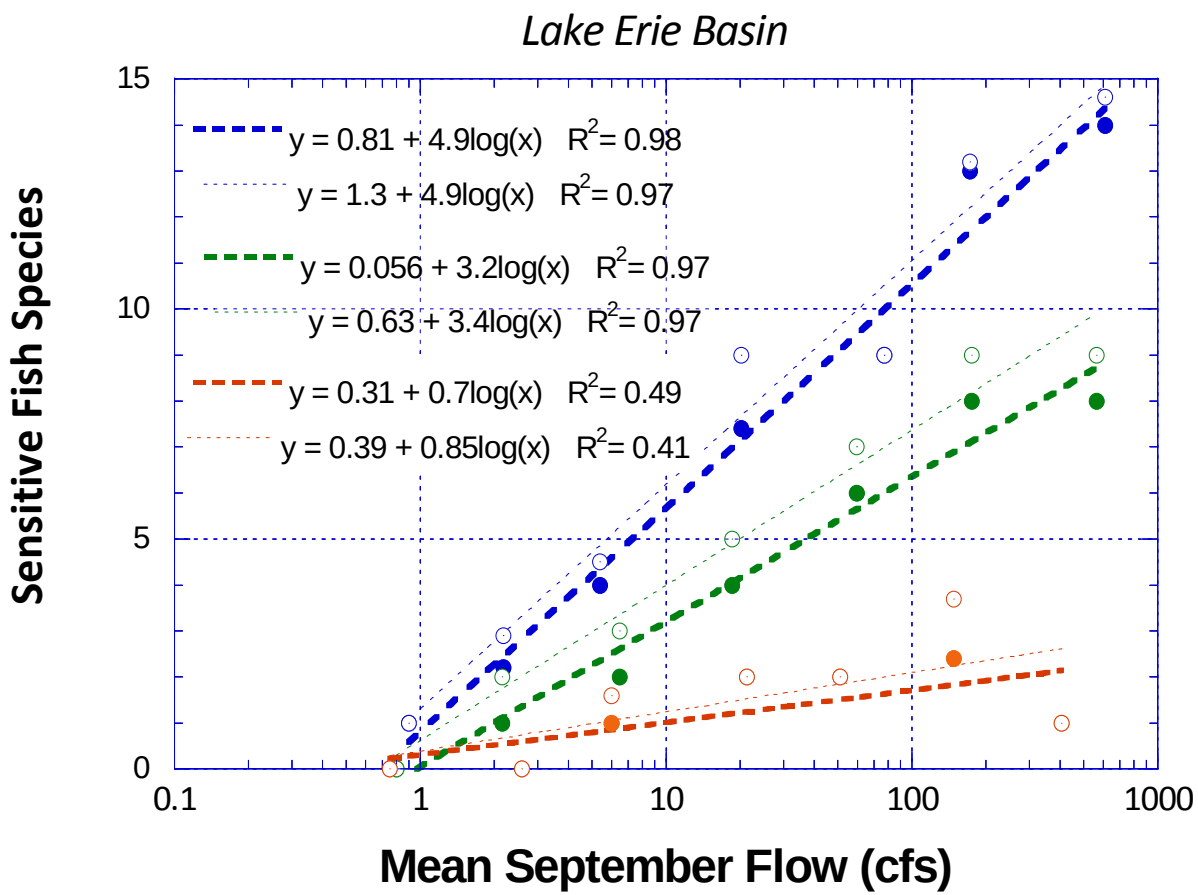




Mean Sept Flow and 7Q10



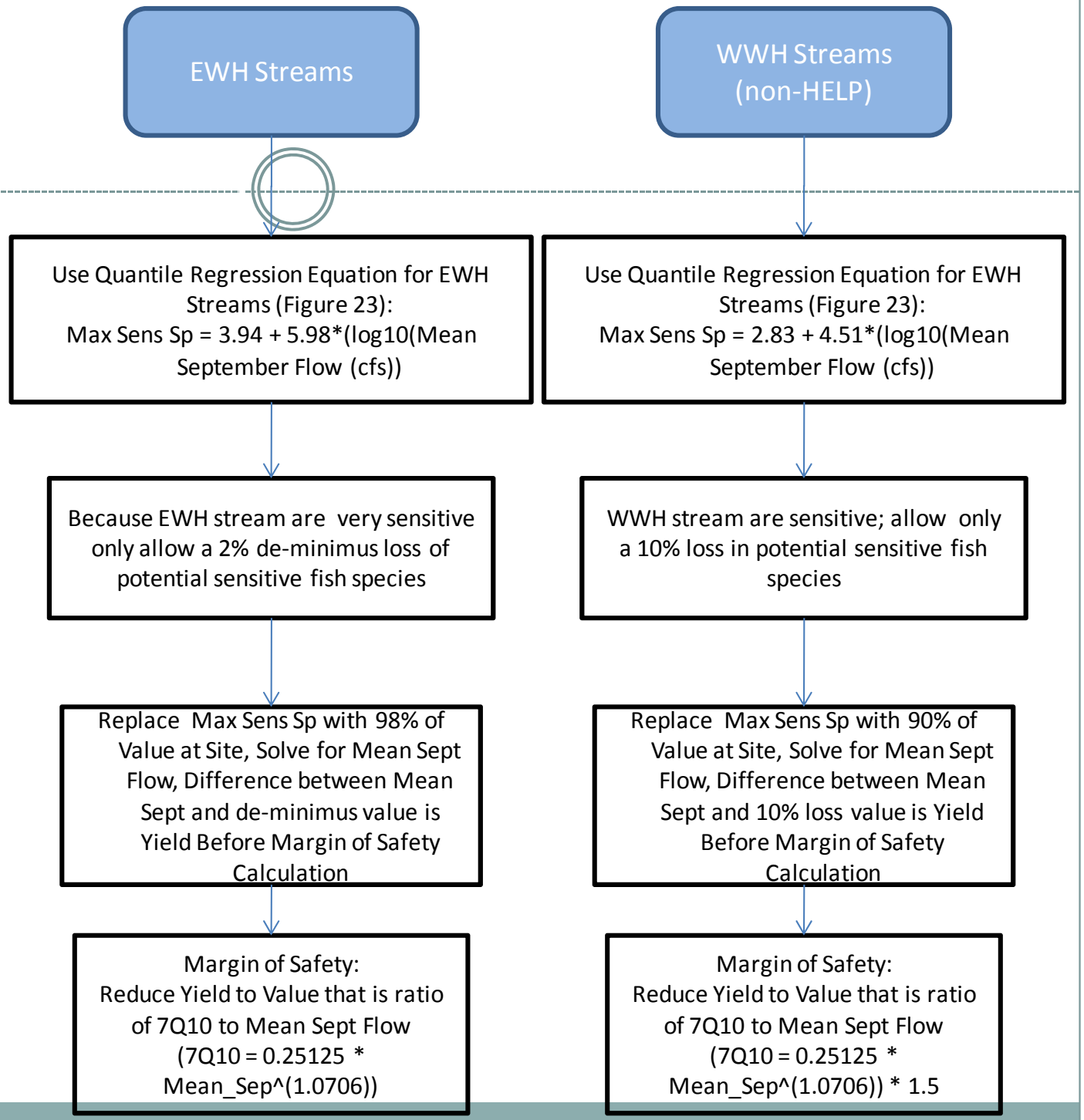
Mean Sept Flow vs. Mean Sens Fish Species by Aq Life Use



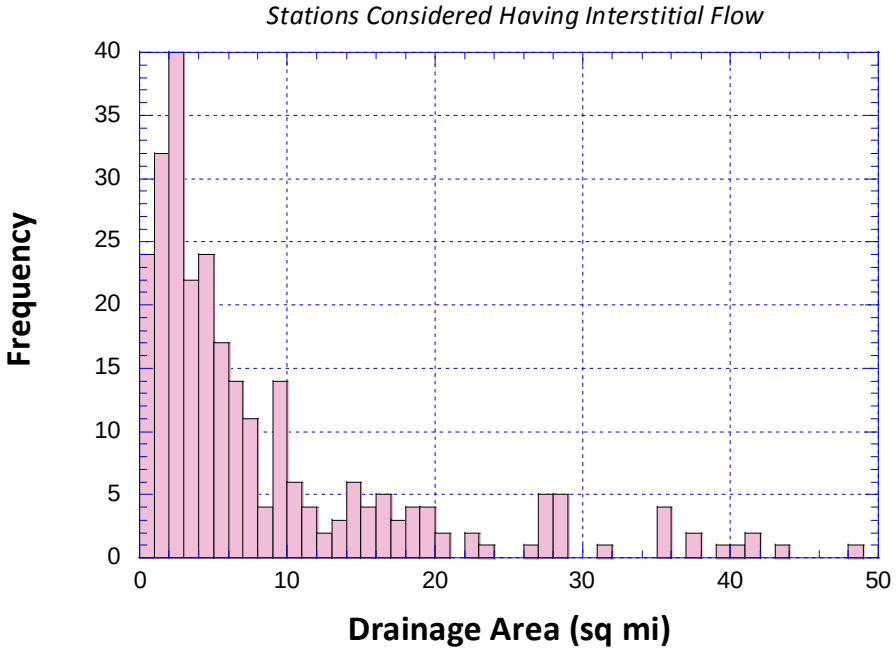
Base Flow and Climate Change

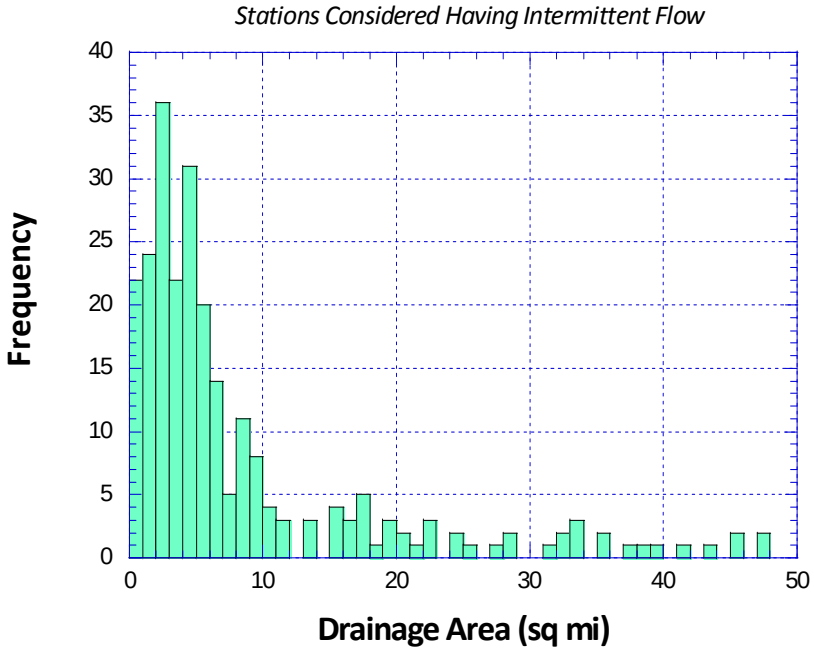
- We described current use related to direct flow withdrawals
- Same concept holds for reductions of baseflow due to precipitation changes and predicted reductions in baseflow
- A loss of habitat
- Geomorphic context: Reductions in base flows and increase in flood flows effects useable habitat; impacts will mirror what we see in urban settings

Setting Flow Withdrawal Thresholds



Issues for Small Headwater Streams: Precision of Flow Estimates





Historical Stream Flow and BCG in Midwest

- Useful to determine what flows were like during natural setting;
- Ohio has a substantial of descriptions of the natural landscape:
  - Trautman (1957) in his Fishes of Ohio summarized many of the historical accounts of Ohio stream flows:
    - "One of the impressive facts, abundantly verified, concerning conditions in primeval Ohio was the great profusion of "durable springs and small brooks," both flowing throughout the year, and the great amount of bog, prairie, and swamp and forest lands which were covered with water during all or much of the year. This abundance of underground and surface water was a prime factor contributing to the great abundance of fishes in Ohio before 1800."

Useful to Place Predicted Climate Related Flow Change in Historical Perspective:

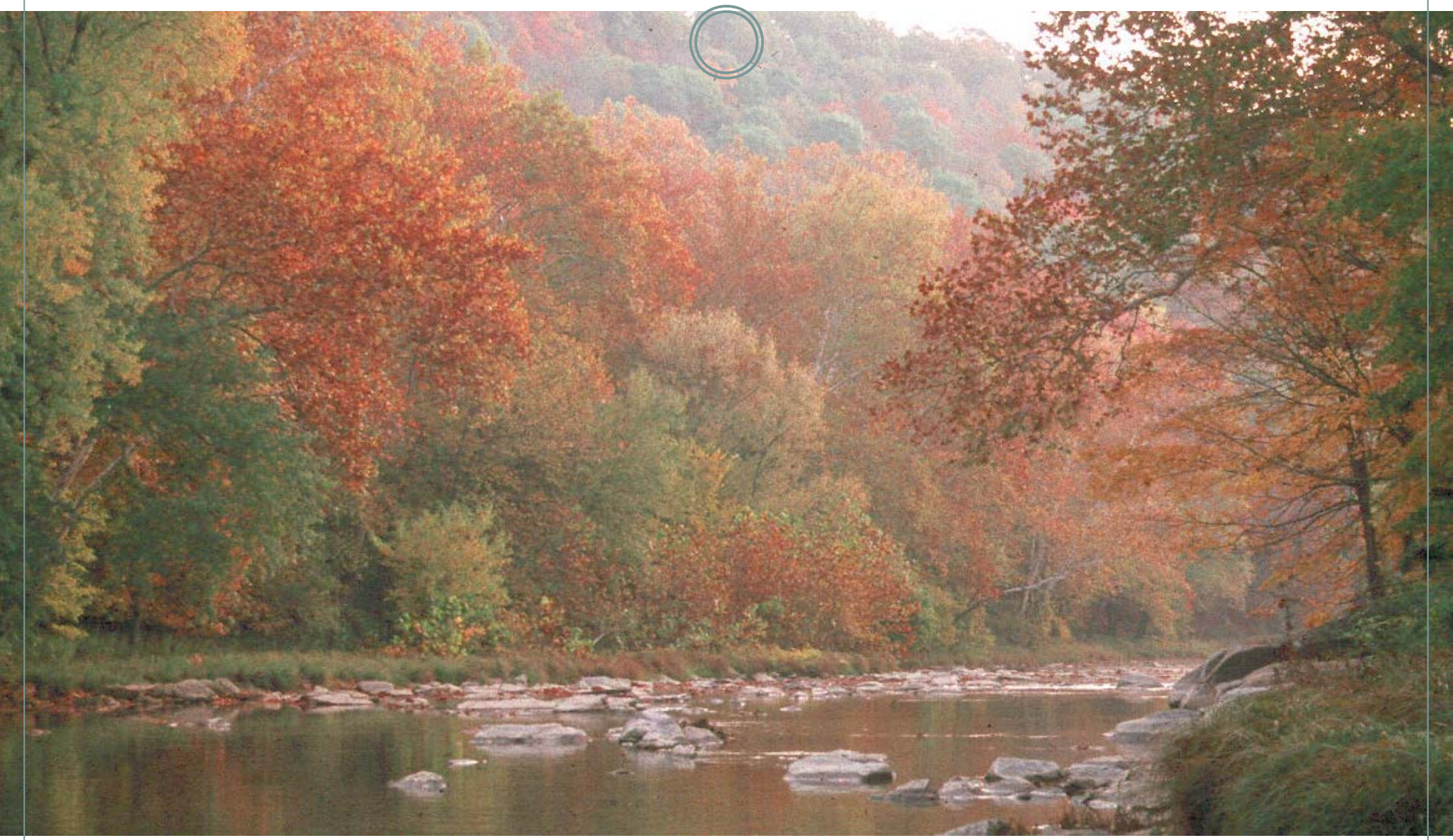
Table 10. Draft narrative description of low flow changes in Ohio streams and rivers along the x-axis of the biological condition gradient relationship with a historical context of hydrological changes in Ohio.

Low Flow Hydrological Conditions (Tier)	Low Flow Characteristics	Explanation
Natural, Undeveloped i.e., "Pristine Anchor" Tier I	Base flows and flow yield statistics maximized; few zero flow days except in tiny headwaters or slopes or during severe natural droughts	Low flow hydrology related to natural precipitation cycles and very strong influence of extensive wetlands across Ohio. Extensive black swamp in Northwest Ohio discourages permanent settlement even by Native Americans except for hunting forays.
Minimally Altered (Tier II)	Minor changes to base flow due to limited agricultural clearing, no substantial artificial drainage	Agriculture and settlement becoming common in early 1800s, but generally where natural drainage permits. Rivers can be used for flatboat or canoe navigation more widely than today because of strong summer base flow during most time periods. Native brook trout still inhabit many Northeast Ohio streams.
Moderately Altered, Natural Channels (Tier III)	Some changes occurred to base flow because of landscape changes to more widespread agriculture and limited primitive drainage; more zero flow days in small streams	Agriculture and settlement becoming more widespread and deforestation widespread because or burning for agriculture or used for building, stream, etc. High flows impacts more substantial than low flow impacts at this time
Moderately Altered, Some Channel Alteration (e.g., Headwaters (Tier IV)	Locally substantial changes to base flow because widespread adoption of agricultural drainage, particularly in headwater streams. Zero flow days more frequent and extensive.	Agriculture and settlement predominant and deforestation widespread. European settlers bring drainage technology from Europe and develop newer technology in Ohio (powered ditching equipment). Drainage of Black Swamp now widespread.
Substantially Altered; i.e., Extensive Drainage, Some Urban (Tier V)	Drainage is widespread where needed. Many small streams that once flowed perennially now empheral; base flow and base flow yields minimized	Drainage extensive through the state where needed for agricultural and wetland loss maximized in Ohio (~ 95% of original wetlands lost). Drainage tends to reduce recharge into aquifers and send flows more quickly downstream minimizing base flow conditions and increase base stream temperatures under most situations (but see Mad River watershed)
Substantially Altered; i.e., Drainage, Highly Impervious (Tier VI)	Drainage is widespread and urban nature of many areas has led to stream being place within stormwater drains or pipes. Many small streams that once flowed perennially now empheral; base flow and base flow yields minimized	See above, however extensive urban impacts can have even more severe high flow impacts which adds geomorphic stresses (stream widening) to already existing hydrological stress (ephermal streams) worsening urban impacts compared to agricultural.

More Conclusions

- Have not had explicit flow data to “plug” into biological associations
- Flow = habitat
- Flow will be important component of climate change issues
- We discussed flow withdrawal issues, but for ecology high, peak and flashy flows likely larger problem

End



“Flow” IBI/ICI – Work Incomplete

Table 1. Weighted stressor values (WSVs) for Hydro-QHEI current metric, Hydro-QHEI depth metric, overall Hydro-QHEI and for maximum Jul-Aug temperature for fish species in headwater streams. Species represent those ranked most sensitive by the weighted metrics scores with cut-offs given for each metric.

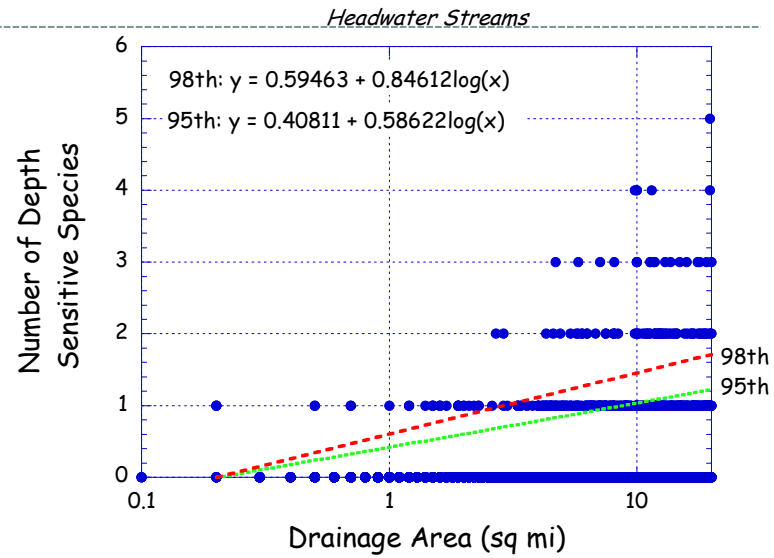
Species	Current > 5	Species	Depth > 7.8	Species	Hydro-QHEI > 12.8	Species	Max. Temp(C) < 22 C
tonguetied minnow	9.3	tonguetied minnow	11.7	tonguetied minnow	21.1	bigmouth shiner	19.0
longnose dace	6.9	bigeye chub	9.1	longnose dace	15.3	brook stickleback	19.4
river chub	6.4	rosyside dace	8.9	bigeye chub	14.0	brown trout	19.9
mimic shiner	5.8	longnose dace	8.4	mimic shiner	13.8	American brook lamprey	20.2
banded darter	5.8	emerald shiner	8.2	rosyface shiner	13.5	longnose dace	20.6
rosyface shiner	5.5	black redhorse	8.0	river chub	13.4	mottled sculpin	20.7
stonecat madtom	5.4	mimic shiner	8.0	banded darter	13.1	northern brook lamprey	20.8
variegate darter	5.3	rosyface shiner	7.9	silver shiner	13.0	least darter	21.4
northern hog sucker	5.2	brown trout	7.8	brindled madtom	12.8	south. redbelly dace	21.5
brindled madtom	5.1	brindled madtom	7.8	black redhorse	12.8	western blacknose dace[1]	21.6
						bigeye chub	21.7
						black redhorse	21.9
						rainbow trout	21.9
						river chub	22.0
						central mudminnow[1]	22.0
						grass pickerel[1]	22.0

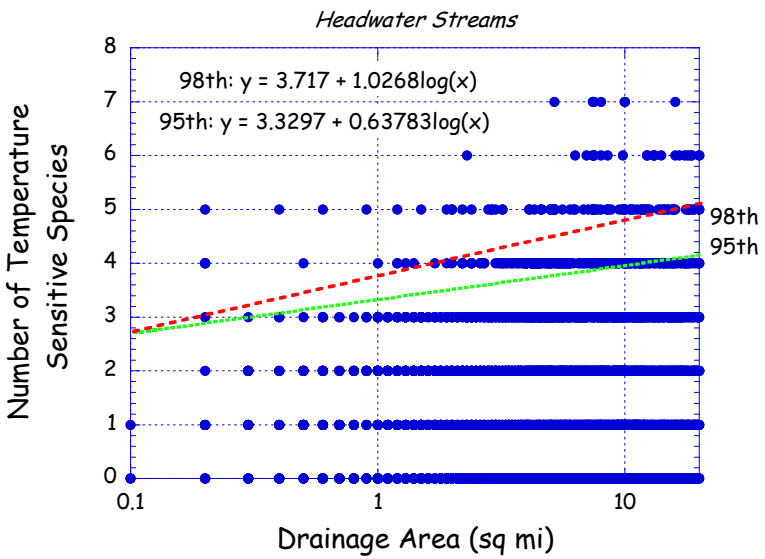
[1]These species are tolerant or partially tolerant and were excluded from the proportional metric

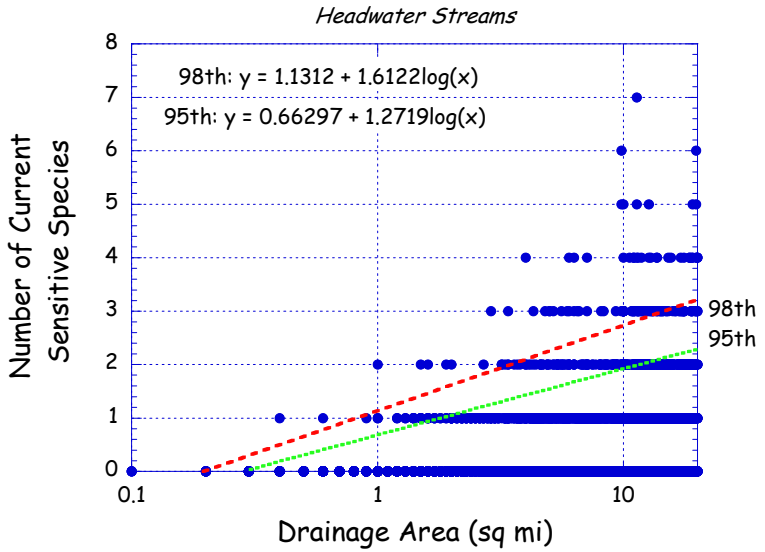
Calibrated Using Continuous Methods

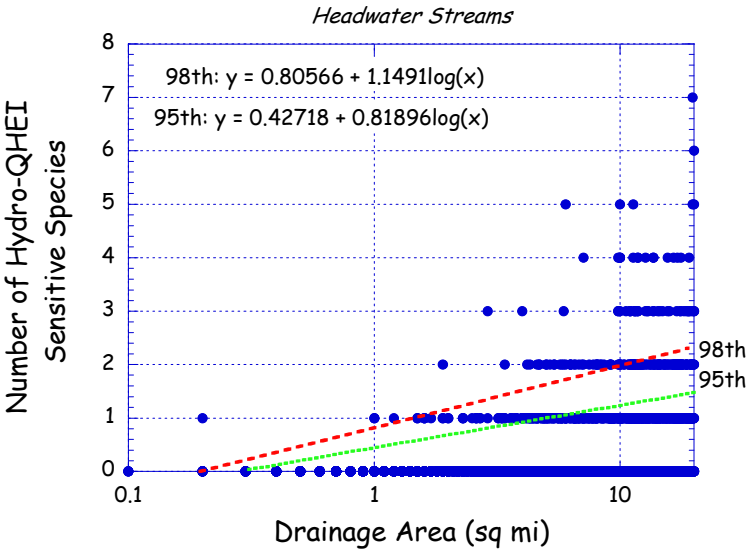
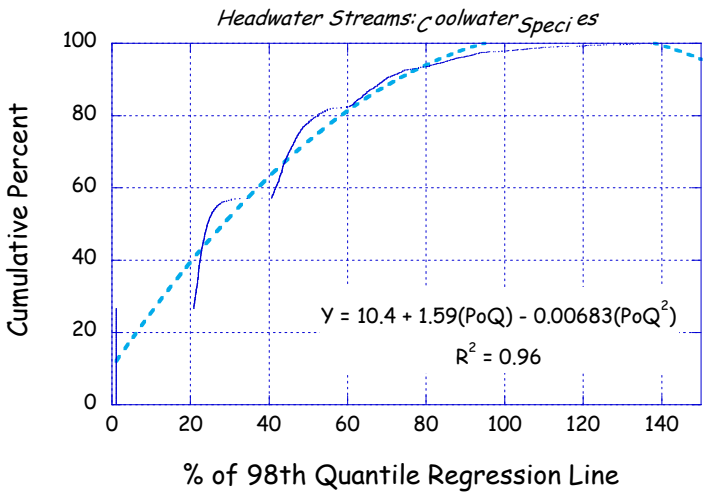
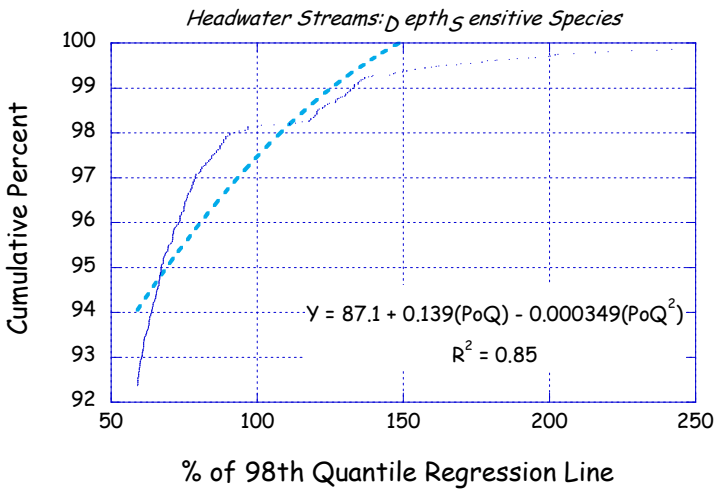
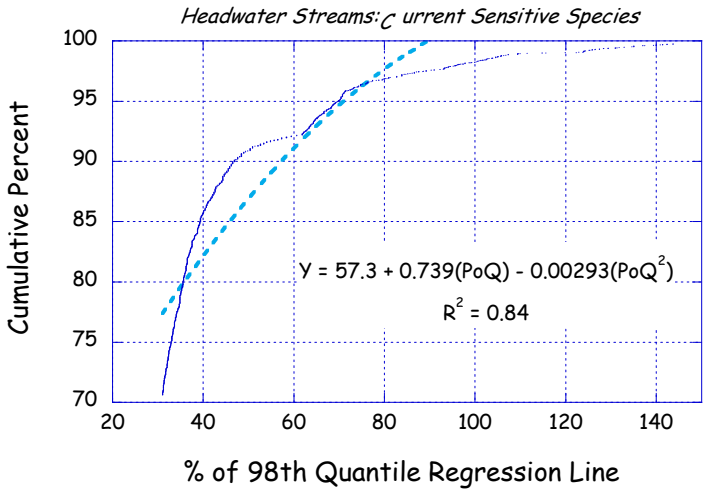
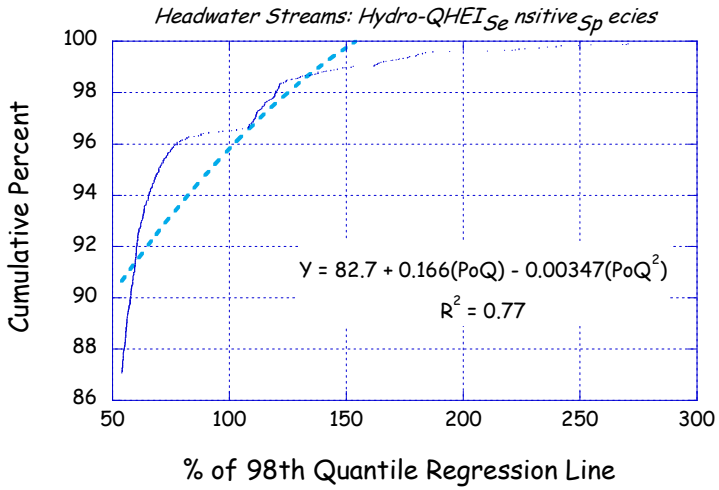
Table XX. Maximum species richness line equations generated by 95th and 98th quantile regression lines generated using USGS Blossom Statistical Software (version W2001.08d)	
Headwater Streams - Fish	
Depth metric	95th: Depth sens. species = 0.40811 + 0.58622log(drainage area, sq mi)
	98th : Depth sens. species = 0.59463 + 0.84612log(drainage area, sq mi)
Current metric	95th: Current sens. species = 0.66297 + 1.2719log(drainage area, sq mi)
	98th : Current sens. species = 1.1312 + 1.6122log(drainage area, sq mi)
Coolwater metric	95th: Coolwater species = 3.3297 + 0.63783log(drainage area, sq mi)
	98th : Coolwater species = 3.717 + 1.0268log(drainage area, sq mi)
Hydro-QHEI metric	95th: HQHEI sens. sp. = 0.42718 + 1.1491 log(drainage area, sq mi)
	98th : HQHEI sens. sp. = 0.80566 + 0.80566log(drainage area, sq mi)
Headwater Streams - Macroinvertebrates	
Depth metric	95th: Depth sens. taxa = 1.24 + 0.8008log(drainage area, sq mi)
	98th : Depth sens. taxa = 1.7454 + 1.0639log(drainage area, sq mi)
Current metric	95th: Current sens. taxa = 2.9058 + 0.90378log(drainage area, sq mi)
	98th : Current sens. taxa = 3.9009 + 0.90057log(drainage area, sq mi)
Coolwater metric	95th: Coolwater taxa = 3.6315 – 0.52675log(drainage area, sq mi)
	98th : Coolwater taxa = 5.9251 – 1.0755log(drainage area, sq mi)
Hydro-QHEI metric	95th: HQHEI sens. taxa = 1.9186 + 0.91636 log(drainage area, sq mi)
	98th : HQHEI sens. taxa = 2.6026 + 1.1547 log(drainage area, sq mi)
Wadeable Streams - Fish	
Depth metric	95th: Depth sens. sp = -0.39326 + 1.5858log(drainage area, sq mi)
	98th : Depth sens. sp = -0.23966 + 1.7601log(drainage area, sq mi)
Current metric	95th: Current sens. sp = 2.9058 + 0.90378log(drainage area, sq mi)
	98th : Current sens. sp = 3.9009 + 0.90057log(drainage area, sq mi)
Coolwater metric	95th: Coolwater sp = 2.0
	98th : Coolwater sp = 3.0
Hydro-QHEI metric	95th: HQHEI sens. sp = -0.43746 + 1.6136 log(drainage area, sq mi)
	98th : HQHEI sens. sp = -0.23966 + 1.7601 log(drainage area, sq mi)

Calibration Plots – Fish Headwater









Scoring Curves – Fish Headwaters