Stream Restoration Performance Assessment

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Bio&Ag ENGINEERING

Sea Grant NORTH CAROLINA

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Natural Channel Design

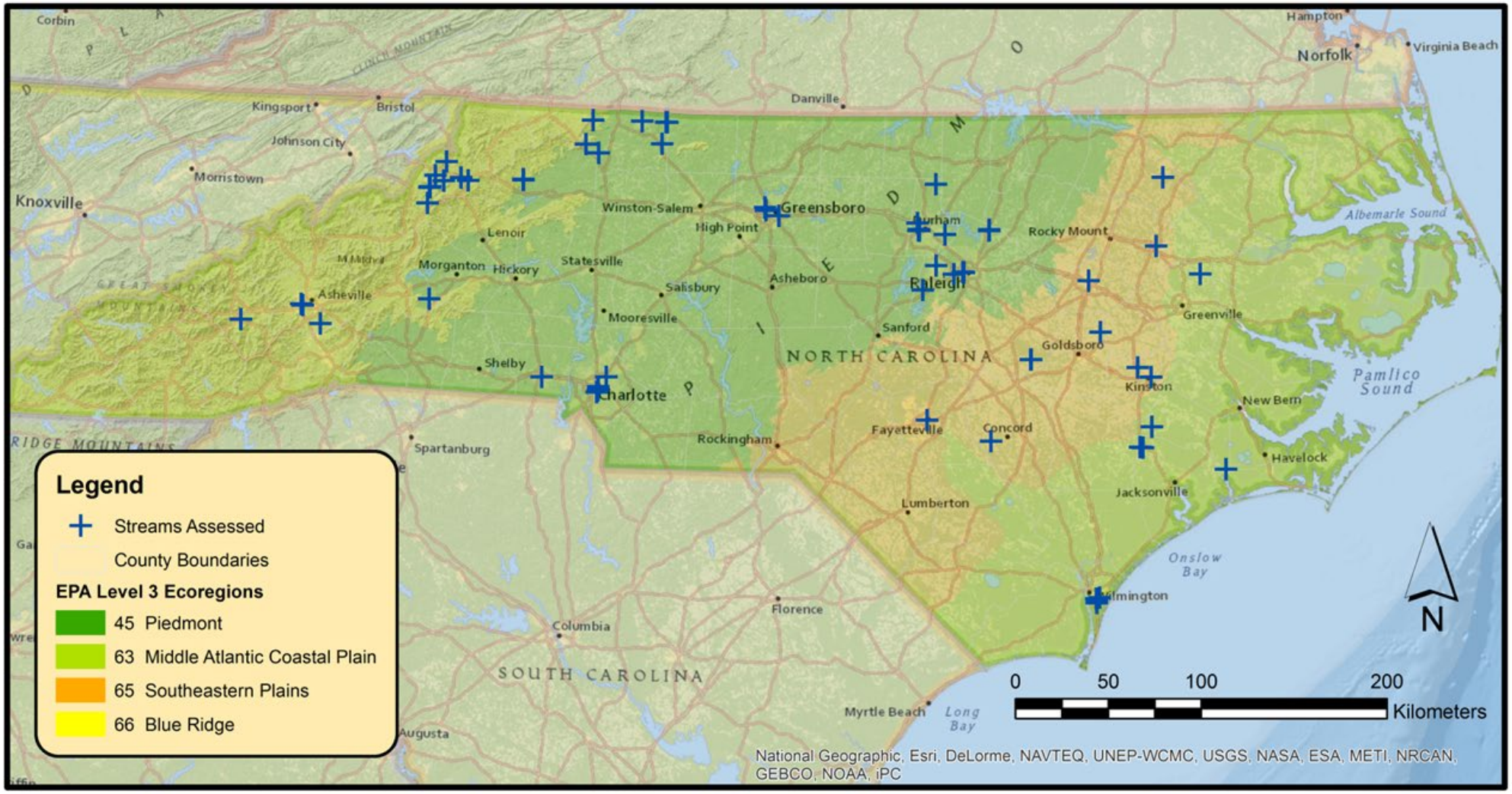
- Fluvial geomorphology-based method for designing natural stable channels developed by Dave Rosgen
- Analogue procedure – morphology measurements are scaled from a natural stable reference stream to determine the restoration design

High-quality “reference” streams serve as design templates

Important Questions

- What tools should be used to evaluate ecological functional uplift of restored streams?
- How do restored streams compare to high quality reference channels?

Tested five stream assessment methods at 65 restored streams
EGA, SPA, RBP, RCE & SVAP



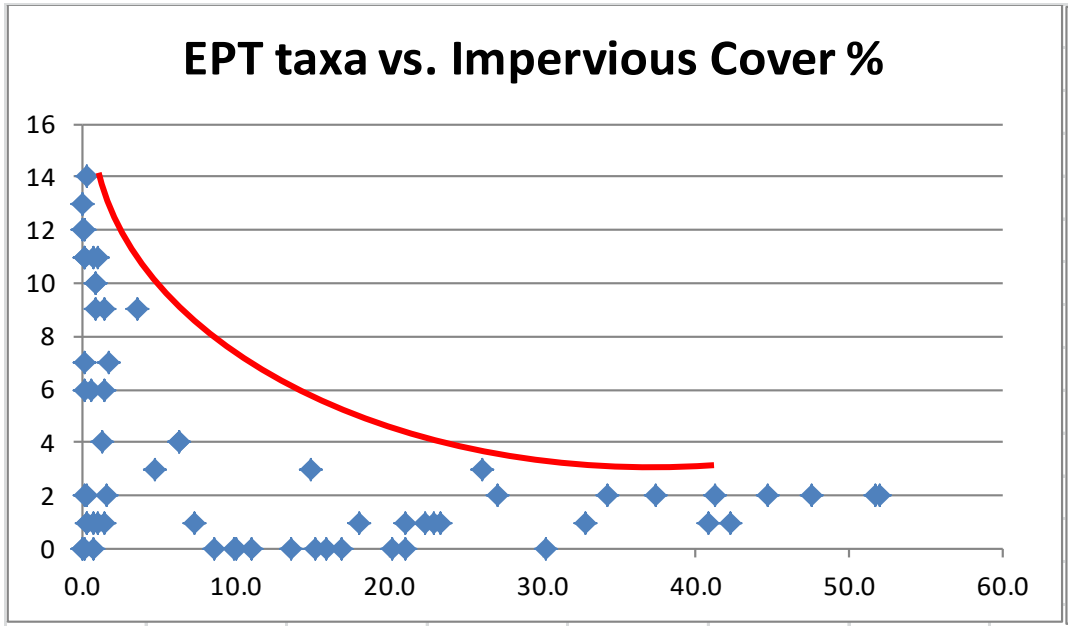
Assessment Methods

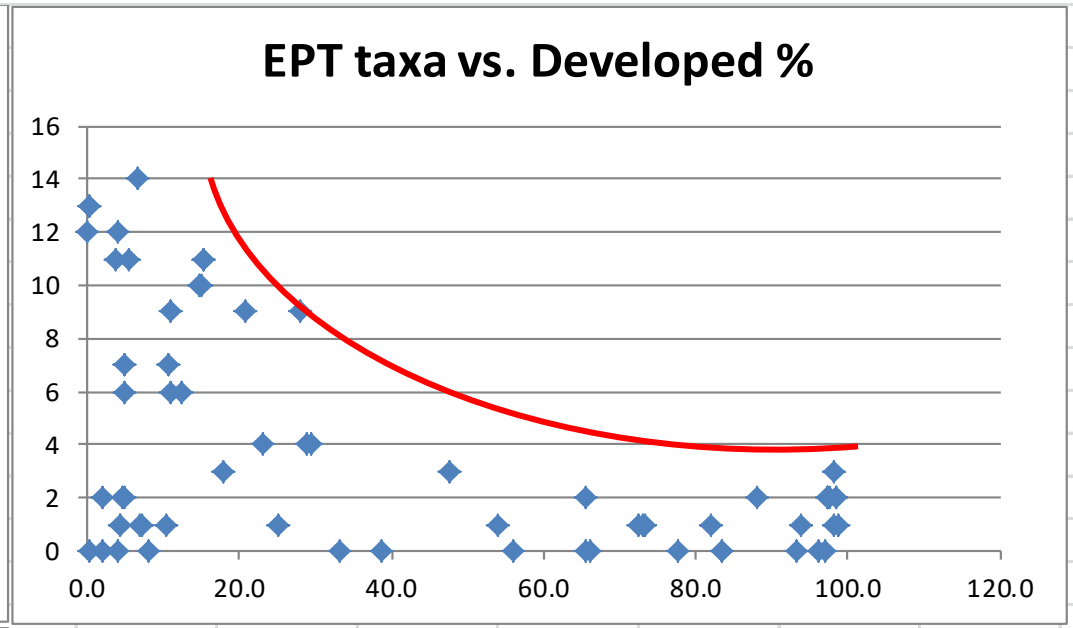
Acronym	Assessment Name	Source	Quantitative	Qualitative	Variables
EGA	Eco-geomorphological Assessment	NCSU	X	X	44
SPA	Stream Performance Assessment	NCSU		X	17
RBP	Rapid Bioassessment Protocol	EPA		X	13
RCE	Riparian, Channel and Environmental Inventory	Peterson (Sweden)		X	18
SVAP	Stream Visual Assessment Protocol	USDA		X	11

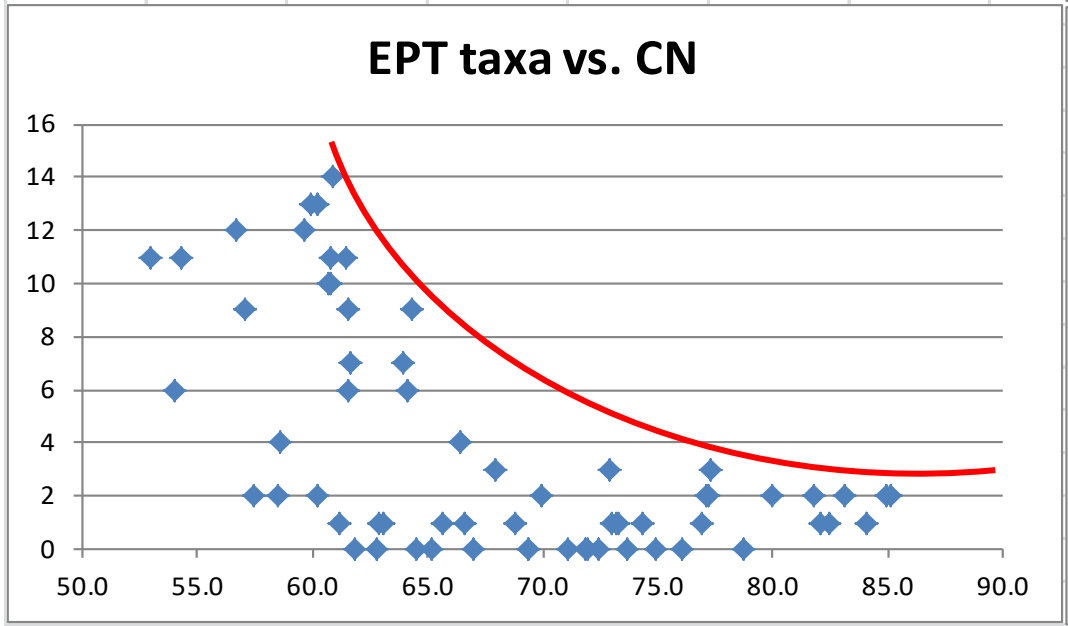
How well do the Stream Assessments predict stream biology?

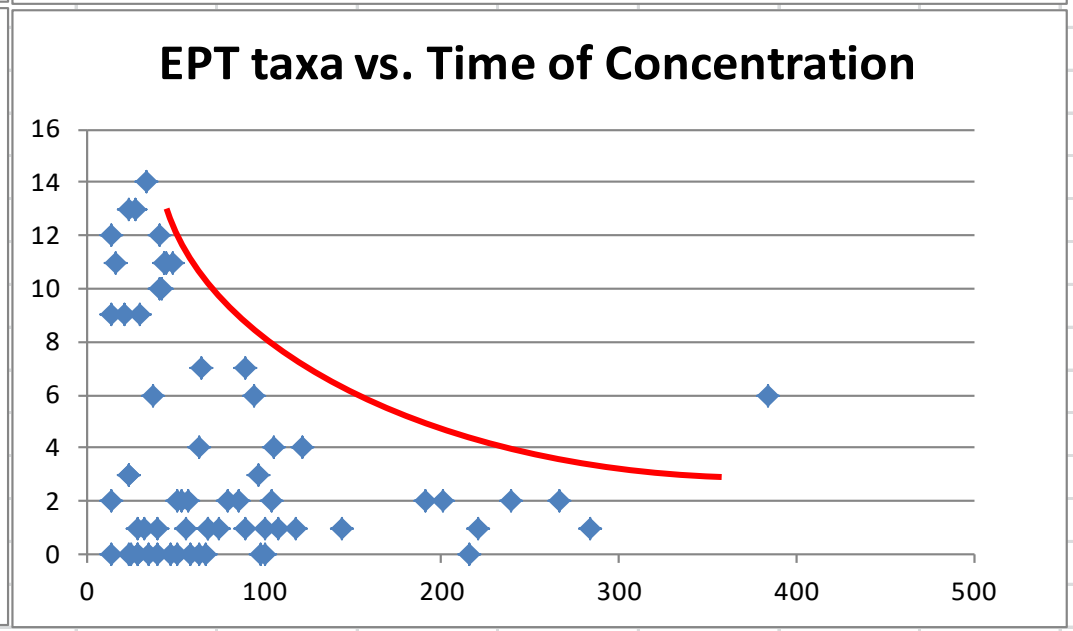
- Response Variable: Number of dominant EPT taxa
- Prediction Models (Regression)

1. Total score
2. All measured metrics individually
3. All measured metrics + watershed condition variables (n=6)


EPT taxa vs. Impervious Cover %
16
14
12
10
8
6
4
2
0
0.0
10.0
20.0
30.0
40.0
50.0
60.0

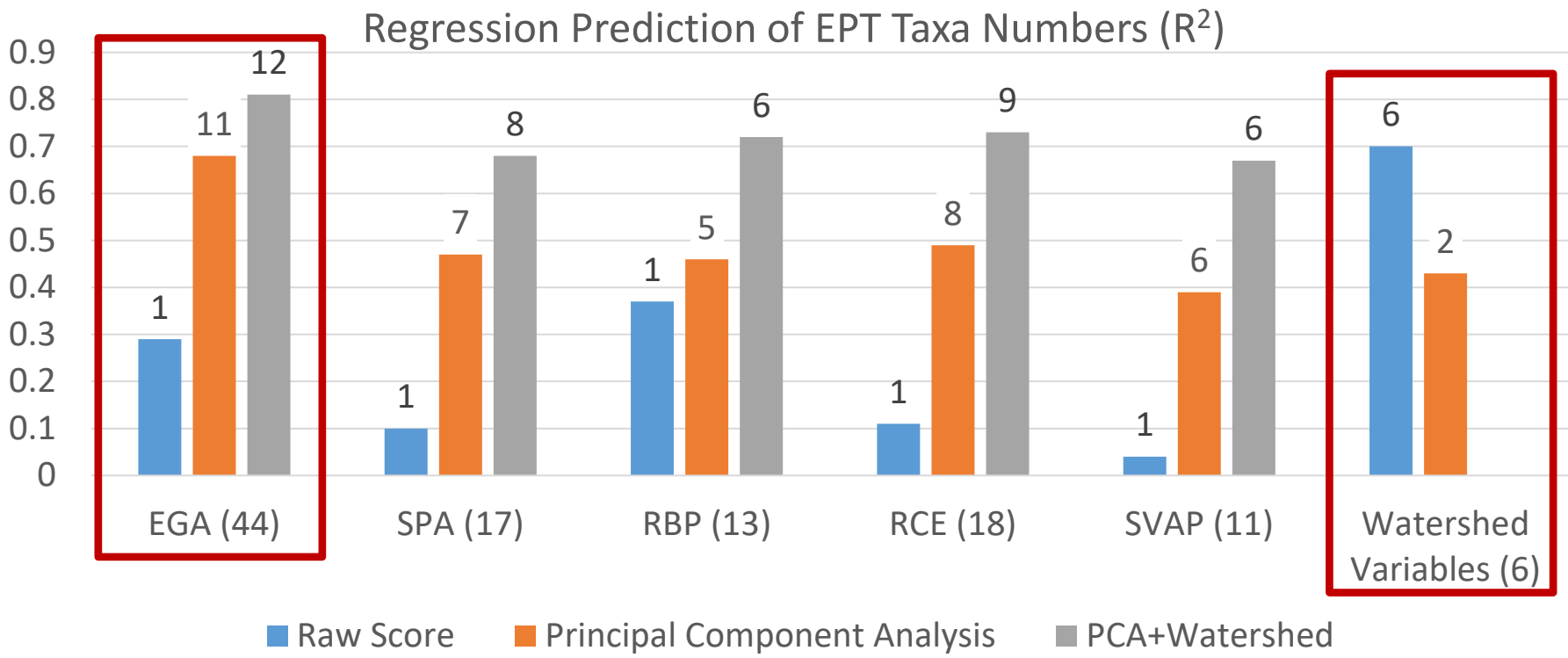

EPT taxa vs. Developed %
16
14
12
10
8
6
4
2
0
0.0
20.0
40.0
60.0
80.0
100.0
120.0


EPT taxa vs. CN
16
14
12
10
8
6
4
2
0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0

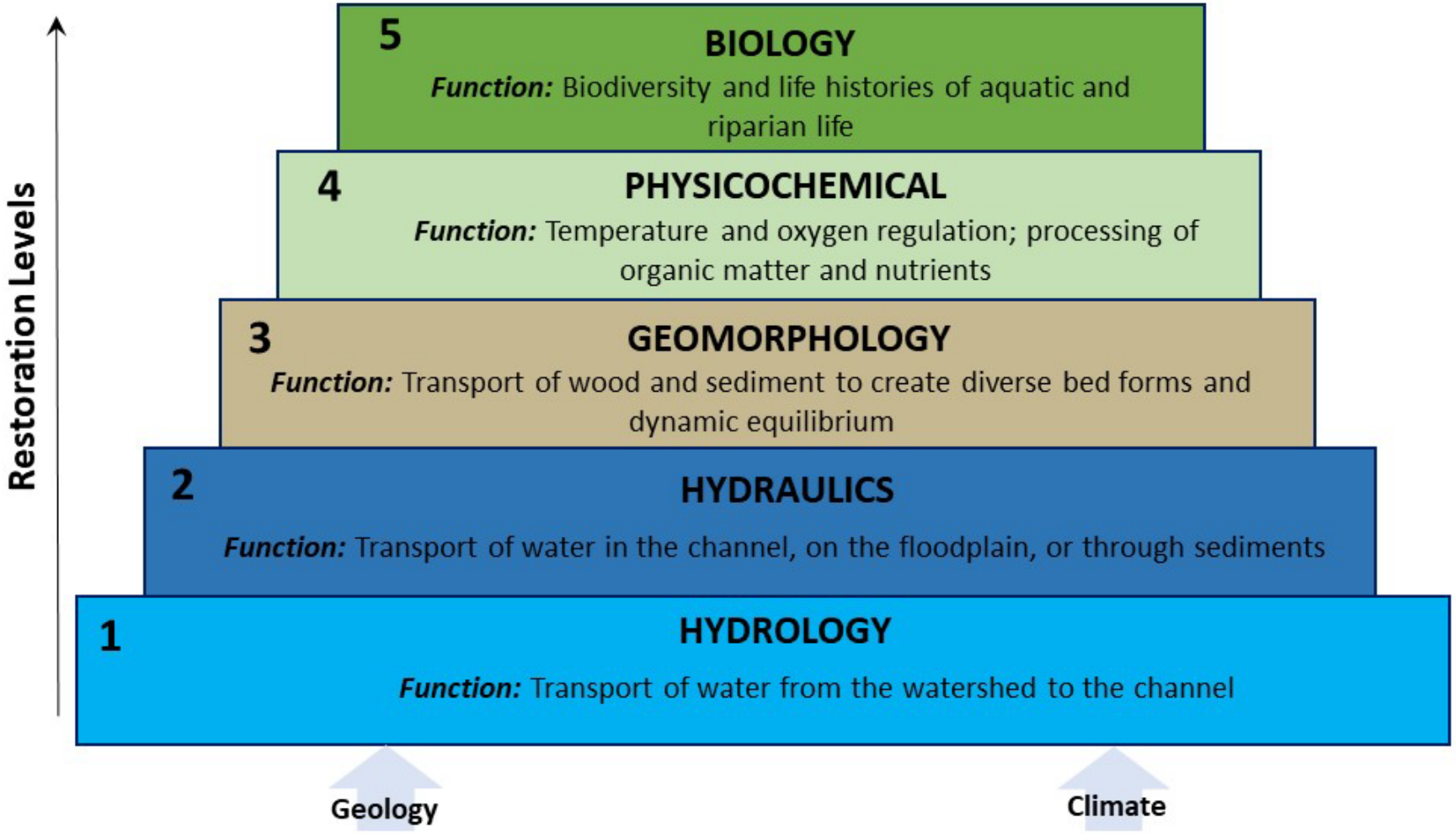

EPT taxa vs. Time of Concentration
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500

Can Rapid Assessments Predict EPT Taxa?

- Eliminate arbitrary averaging and summing of variables & add watershed factors
- Re-weight variables and address collinearity of variables using ordination statistics (Principal Component Analysis)
- Apply Multiple Linear Regression using Principal Components that explain 70% of the variability

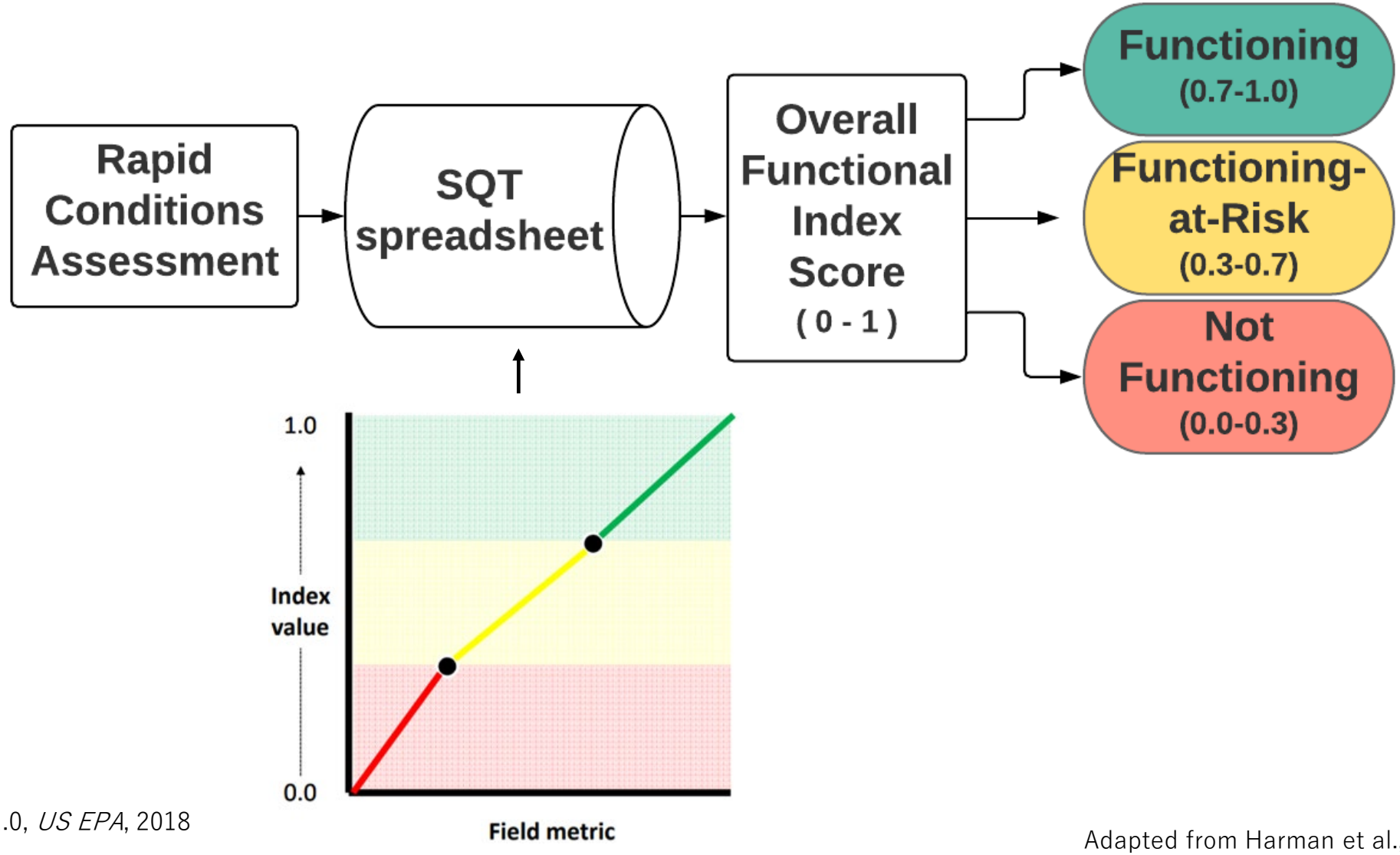


Stream Quantification Tool (SQT) based on the stream functions pyramid framework



Adapted from Harman et al., 2012, *US EPA*

Evaluating the Stream Quantification Tool (SQT): Measure & Quantify Function



SFAM, Version 1.0, *US EPA*, 2018

Adapted from Harman et al., 2017

Functional Category	Measurement Method
Hydrologic	Curve Number (catchment)
	Curve Number (lateral)
	Concentrated Flow Points
	Soil Compaction
Hydraulic	Bank Height Ratio
	Entrenchment Ratio
Geomorphic	LWD Index
	Large Woody Debris Piece Count
	Erosion Rate
	Dominant BEHI/NBS
	Percent Streambank Erosion
	Canopy Coverage
	Buffer Width
	Basal Area
	Stem Density
	Pool Spacing Ratio
	Pool Depth Ratio
	Percent Riffle
	Aggradation Ratio
	Sinuosity
	Size Class Pebble Count Analyzer

Functional Category	Measurement Method
Physico-chemical	Total Nitrogen
	Total Phosphorus
	Leaf Litter Processing Rate OR Percent Shredders
	Fecal Coliform
	Summer Daily Max. Temp.
Biological	NC Biotic Index for Macroinvertebrates
	EPT Index
	NC Index of Biotic Integrity for Fish
Restoration Potential	Watershed Catchment Assessment

Total SQT Variables= 28

Performance Standard Values of 1.0 are intended to represent pristine streams

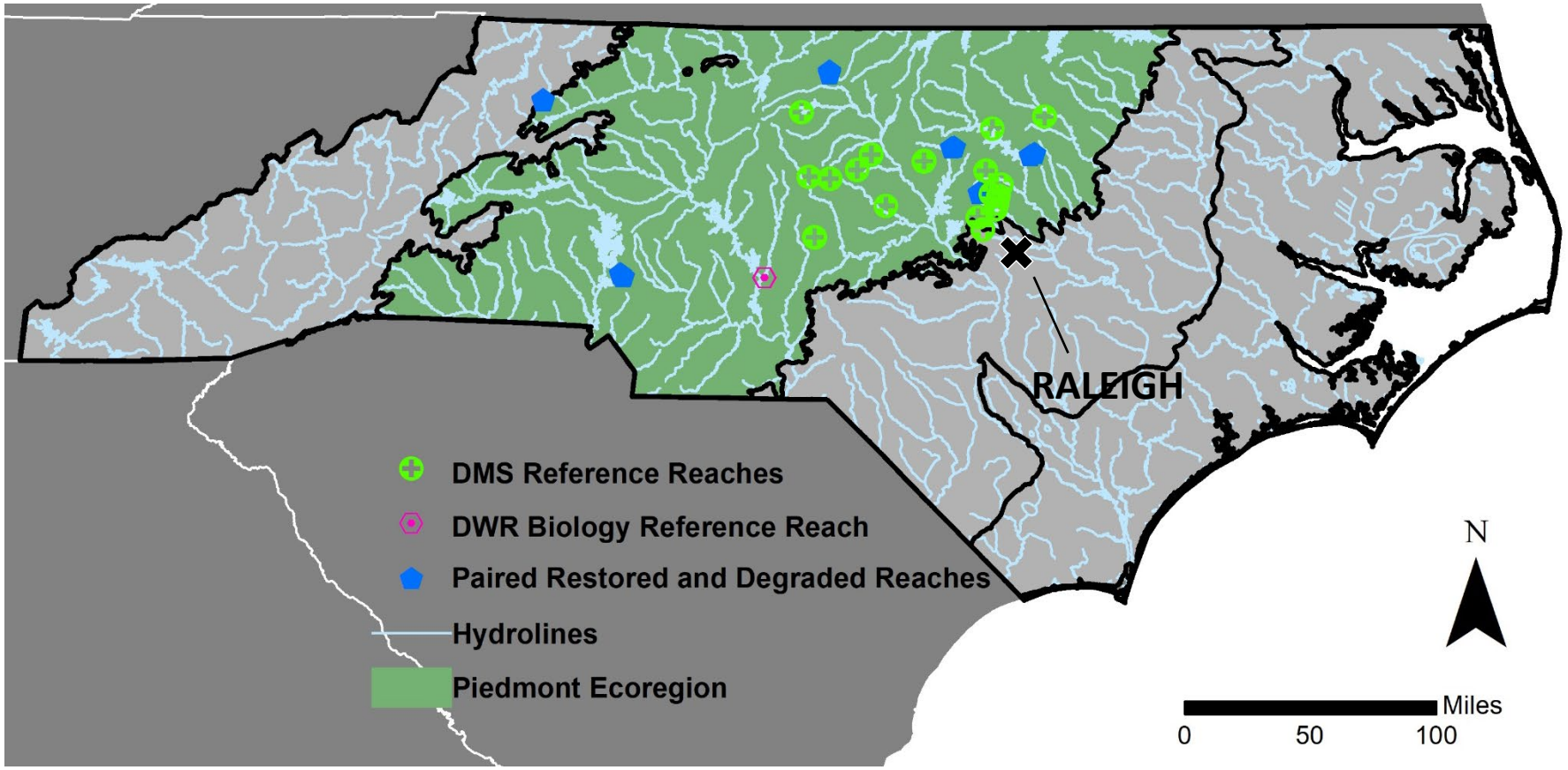
Research Questions

- **Can the SQT Detect and Quantify Restoration Success?**
- **How do the Performance Standards compare to High Quality and Degraded Streams?**
- **How well does the SQT predict biology?**

Site locations and selection (n=34)

- Reference Reaches (n=19)
- Degraded Streams (n=6)
- Restored Streams (n=9)

- DAs < 8.6 sq. mi.
- Watershed land use range
- Stream orders 1 - 3
- Restored sites > 5 years old



Methods

Functional Category	Measurement Method
Hydrologic	Curve Number (catchment)
	Curve Number (lateral)
	Concentrated Flow Points
	Soil Compaction
Hydraulic	Bank Height Ratio
	Entrenchment Ratio
Geomorphic	LWD Index
	Large Woody Debris Piece Count
	~~Erosion Rate~~
	Dominant BEHI/NBS
	Percent Streambank Erosion
	Canopy Coverage
	Buffer Width
	Basal Area
	~~Stem Density~~
	Pool Spacing Ratio
	Pool Depth Ratio
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Functional Category	Measurement Method
Physico-chemical	Total Nitrogen
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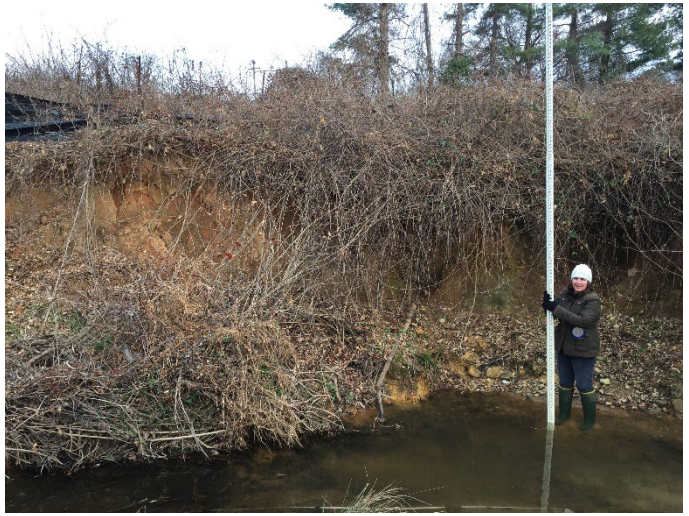
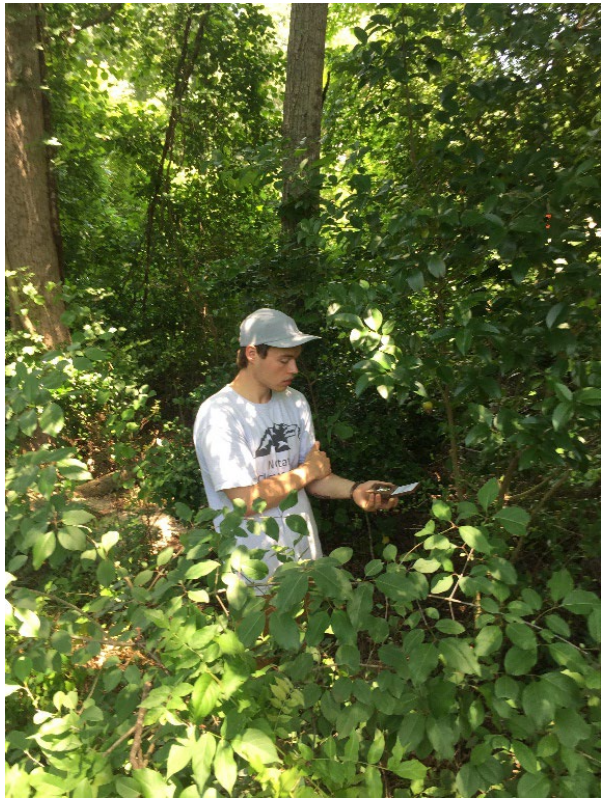
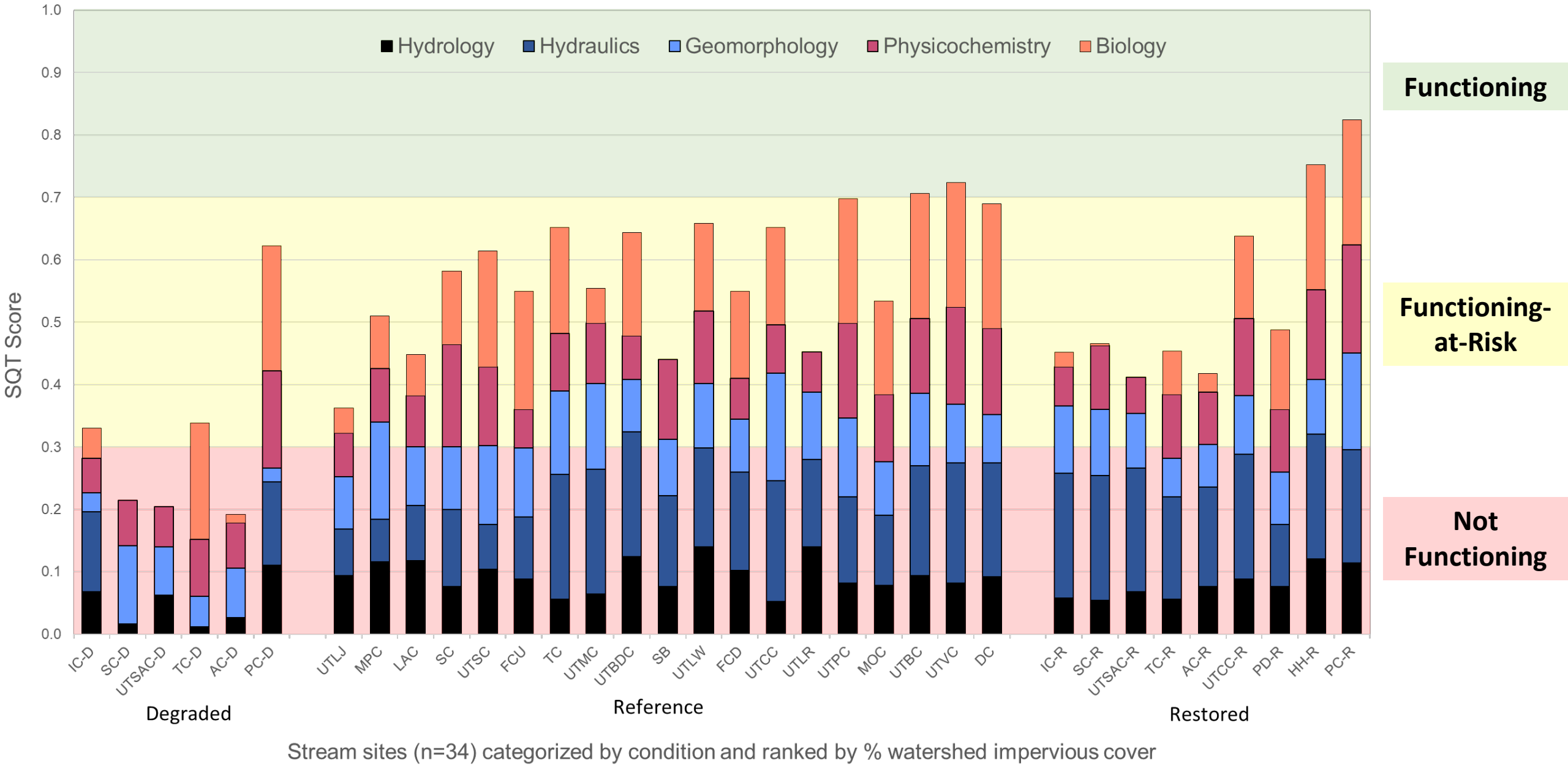
	Fecal Coliform
	Summer Daily Max. Temp.
Biological	NC Biotic Index for Macroinvertebrates
	EPT Index
	~~NC Index of Biotic Integrity for Fish~~
Restoration Potential	Watershed Catchment Assessment

- Assessed 24 of 28 variables
- Evaluated 22 performance standards
- Completed catchment assessment





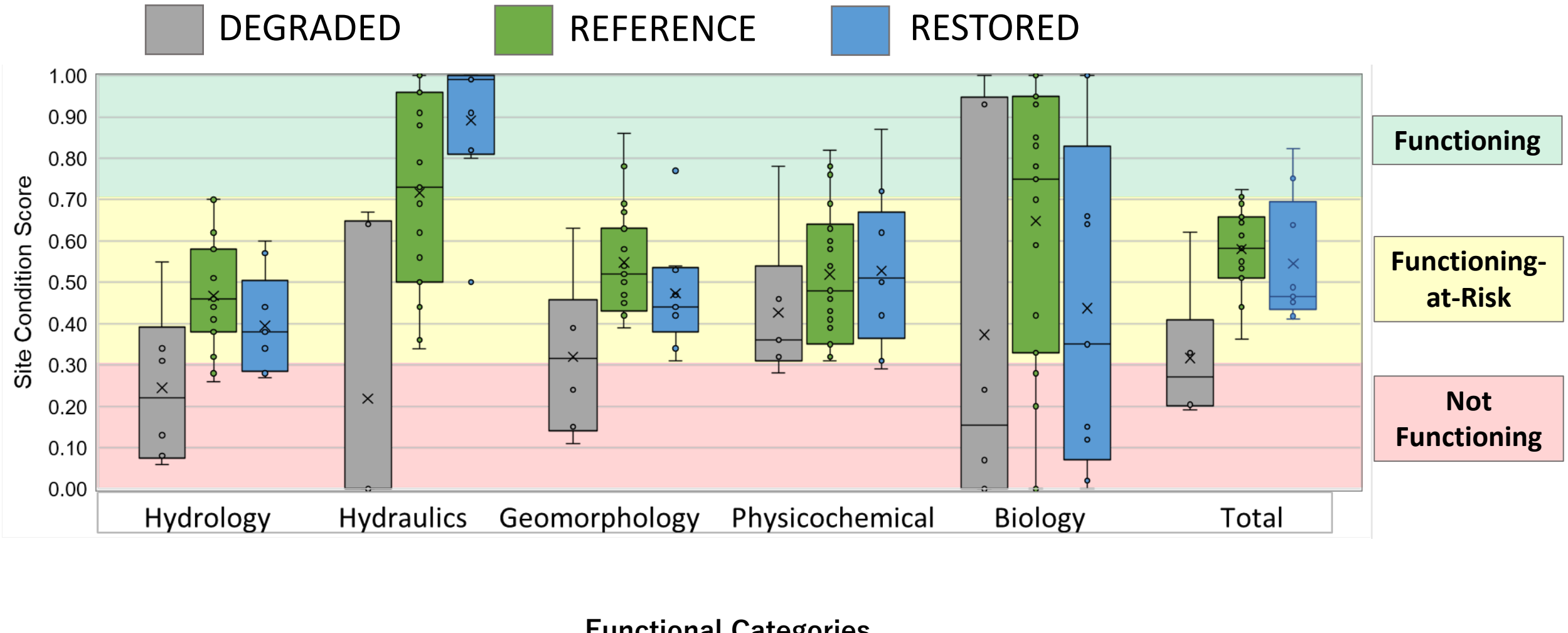


Stream sites (n=34) categorized by condition and ranked by % watershed impervious cover

Range of SQT Overall Scores and Functional Category Scores

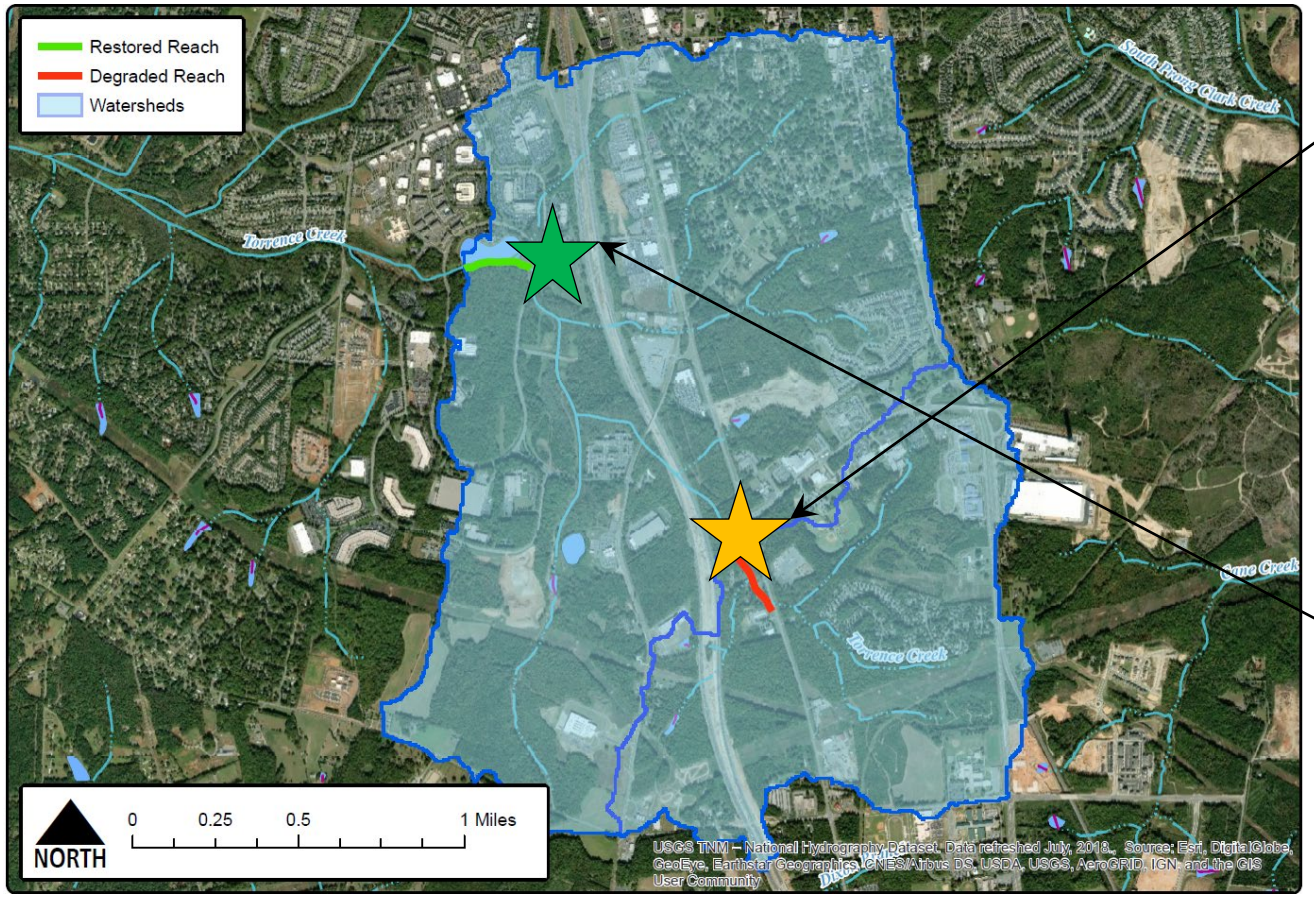
degraded (n=6), reference (n=19), and restored (n=9)



Reference Sites (n=19)

Restoration case studies

Torrence Creek (Charlotte): Suburban Watershed



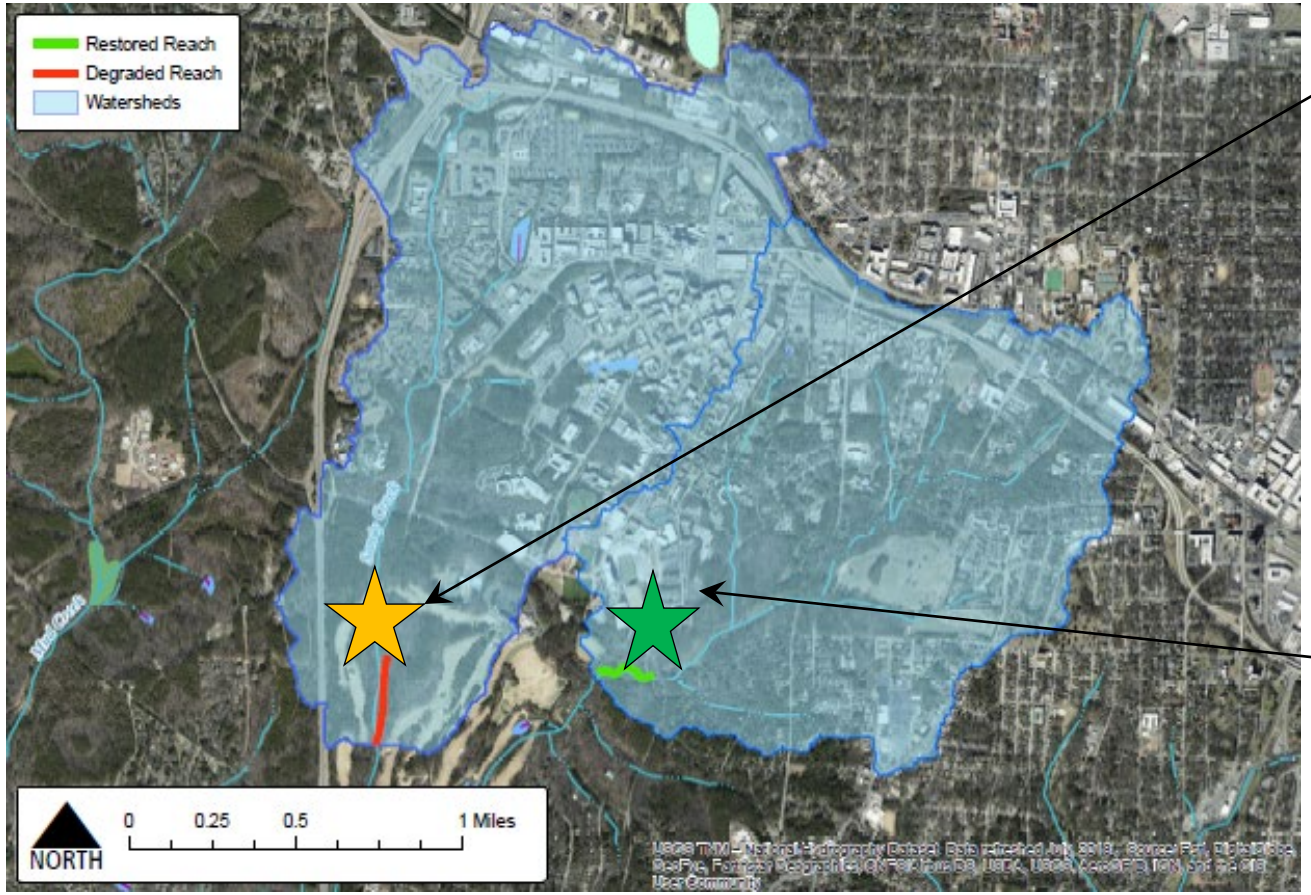
Degraded

Restored (2013)

DA (sq. mi)	Curve Number	Median Particle	Slope (%)	Rosgen Stream Type
1.1	79	Sand	0.62	G5c
3.6	77	Sand	0.36	C5

Restoration case studies

Sandy Creek (Durham, NC): Urban watershed

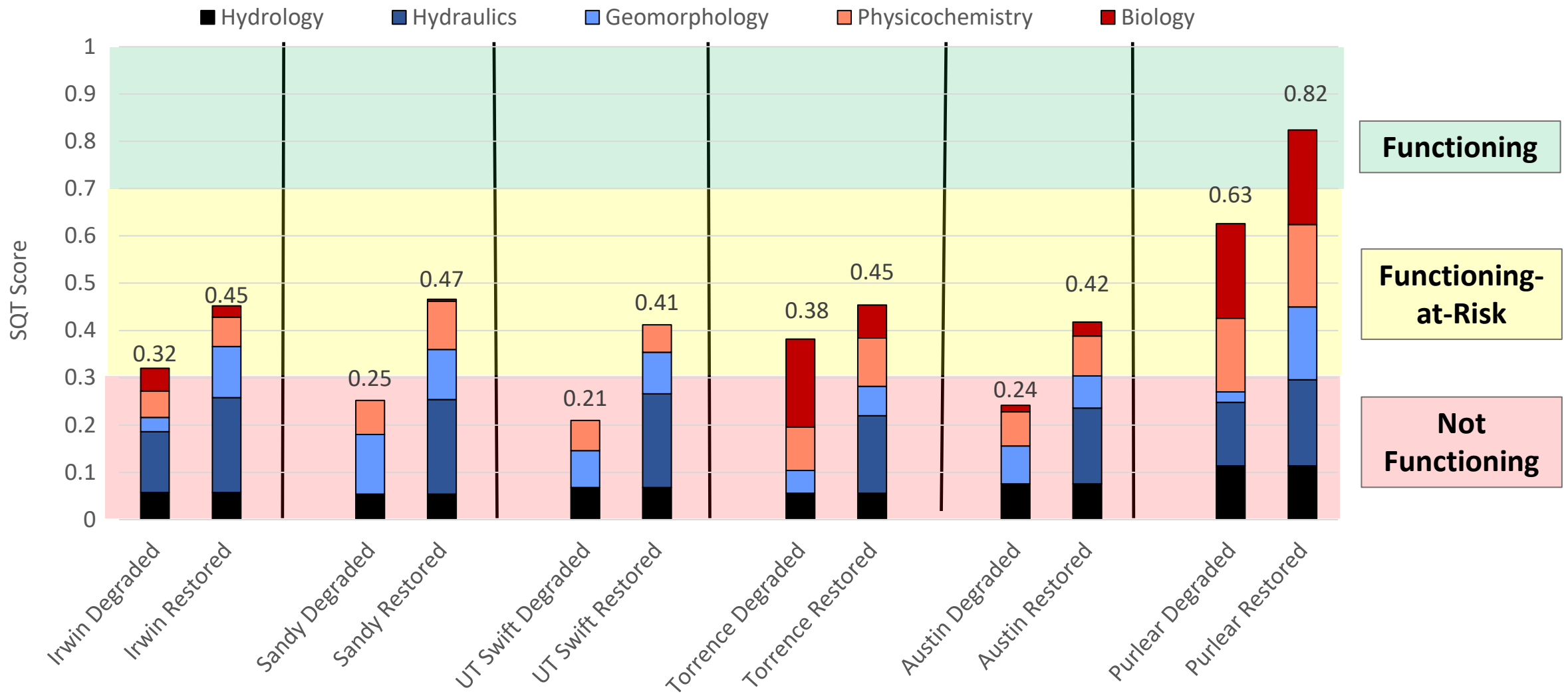


Degraded

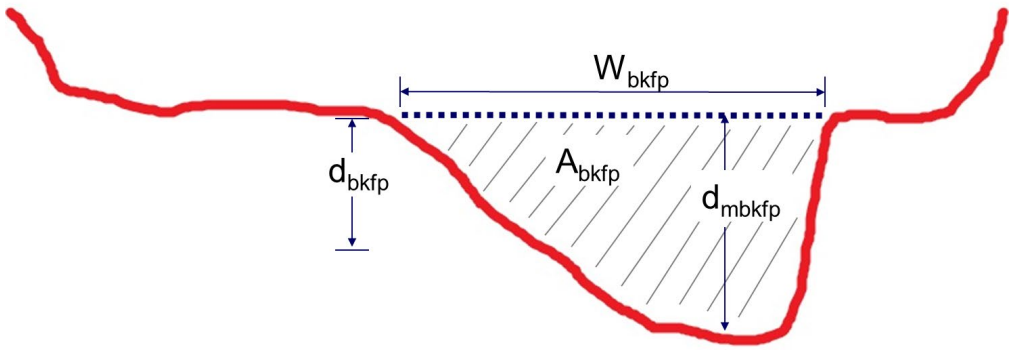
Restored (2005)

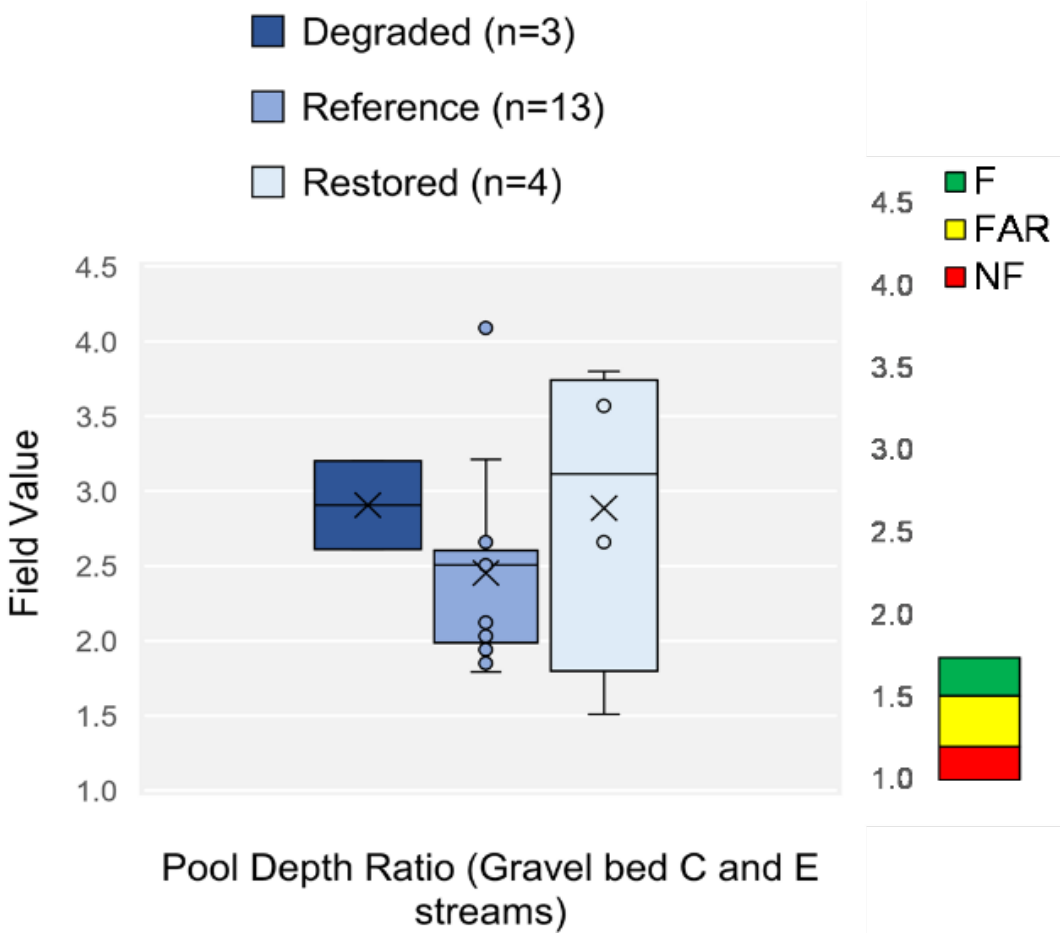
DA (sq. mi)	Curve Number	Median Particle	Slope (%)	Rosgen Stream Type
2.0	85	Sand	0.27	F5
1.8	82	Sand	0.23	E5b

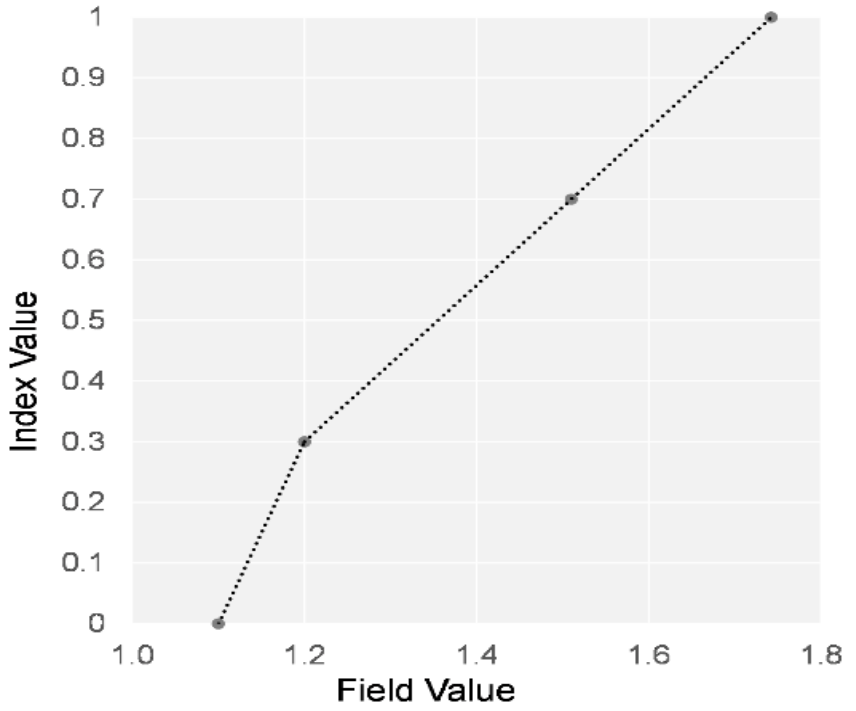
Restored/Degraded Pairs – SQT Scores



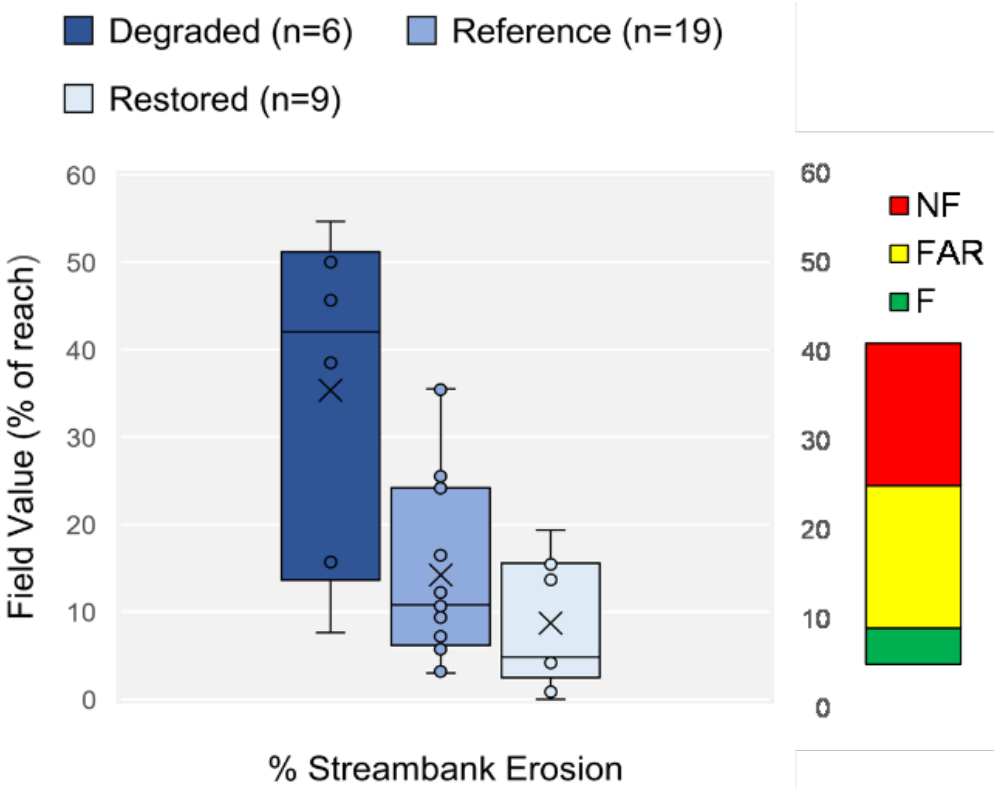
Geomorphic: Pool Depth Ratio (Gravel bed C and E streams)

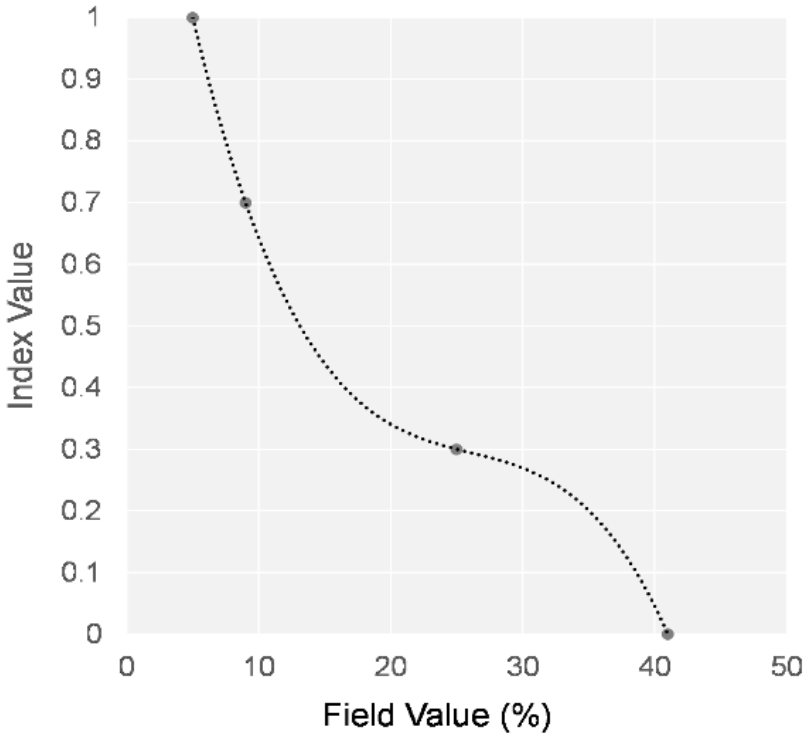






Geomorphic: Percent Streambank Erosion





Which metrics are most important to macroinvertebrates?

Response variables:

- EPT Richness
- NC Biotic Index (NCBI)

Stepwise, Ridge & Lasso Statistical Models

	22 Variables (SQT Model)	+ 13 Variables (Full Model)
Watershed Hydrology	Runoff Curve Number	Drainage Area (DA)
	Concentrated Flow Points	% Impervious Cover
	Soil Compaction	% Developed
Channel Hydraulics	Bank Height Ratio (BHR)	% Forest
	Entrenchment Ratio (ER)	% Agriculture
Geomorph.	Large Woody Debris Index	Channel Slope (S_{avg})
	Bank Erosion Hazard Index	Channel Width (W_{bkf})
	Near Bank Stress	Channel Mean Depth (d_{bkf})
	% Streambank Erosion	Channel Area (A_{bkf})
	Canopy Coverage	Width-to-Depth Ratio (W/D)
	Buffer Width	D_{50}
	Basal Area	D_{84}
	Pool Spacing Ratio	
	Pool Depth Ratio	
	% Riffle	
	Sinuosity	
Physioco-chem.	Total Nitrogen	Specific Conductivity
	Total Phosphorus	
	% Shredders	
	Summer Temperature	
	Fecal Coliform	
	% Shredders	

Which metrics are most important to macroinvertebrates?

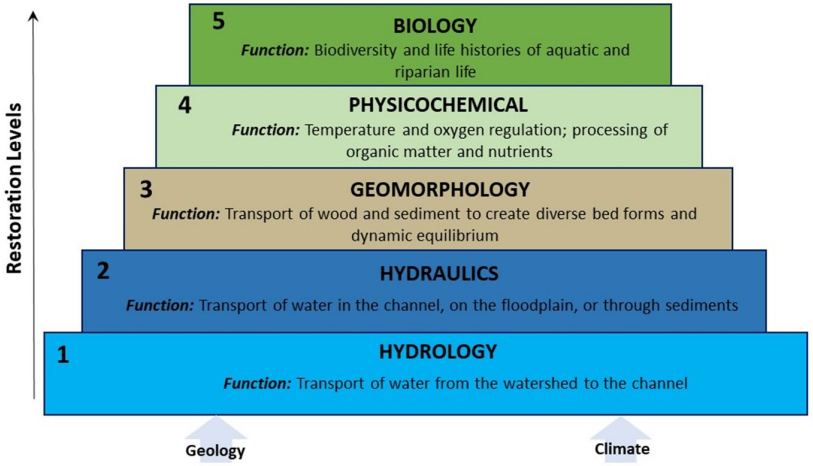
Significant Variables from Stepwise Models for EPT Taxa

SQT Model; $R^2 = 0.64$

- **- NBS**
- **- BEHI**
- **- % Streambank Erosion**
- **- Pool Depth Ratio**
- **- Summer Temp**

- **Full Model; $R^2 = 0.88$**

+ Entrenchment Ratio
+ Width to Depth Ratio
+ Mean Depth
- BEHI
+ Buffer Width
- Pool Depth Ratio
+ % Riffle
+ D_{84}
- Summer Temp



Conclusion

- If we take into consideration watershed condition, rapid stream assessments can predict aquatic macroinvertebrate metrics in restored streams.
- Variables must be weighted based on their importance to biology
- Be sure performance standards match to desirable reference conditions
- Be sure to include all variables that are important to biology

Degraded

Reference

Restored