An Examination of the Impact of Urbanization on Stream Biodiversity and Ecosystem Function

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Charlotte-Mecklenburg STORM WATER Services

UNIVERSITY OF NORTH CAROLINA CHARLOTTE

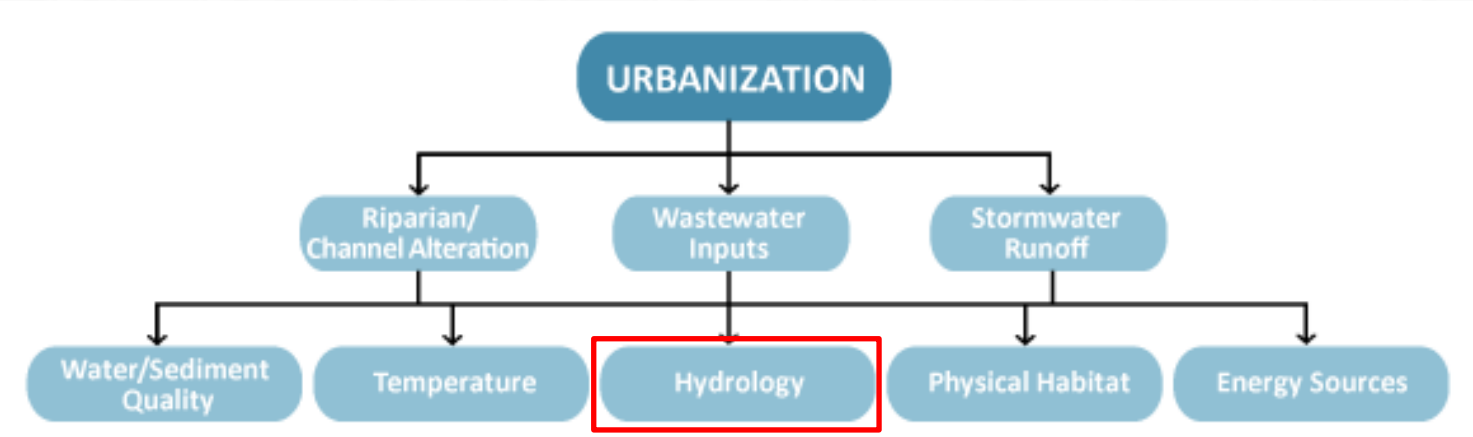
Natural Stream Ecosystem

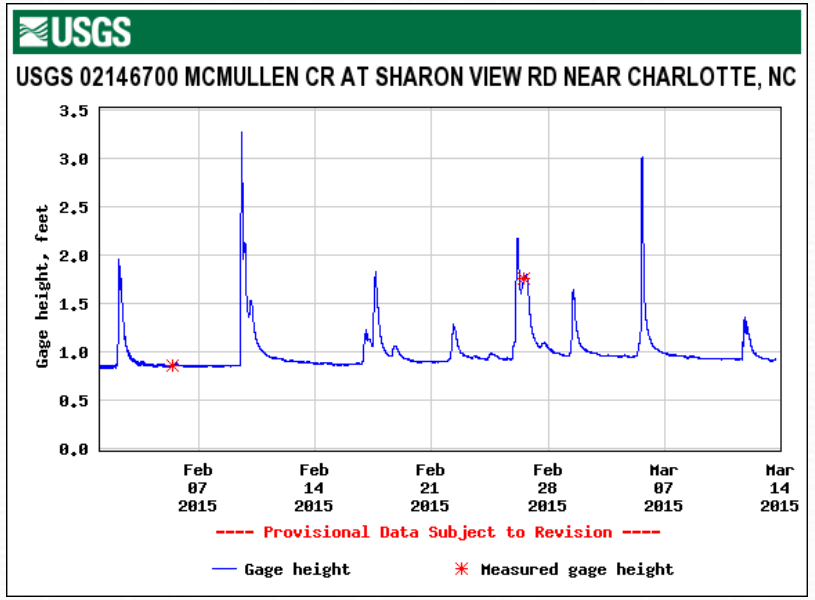
- Diverse heterogeneous substrates that provides habitats for a diversity of aquatic organisms.
- Natural hydrological regime that provides a diversity of flow conditions.
- Vegetative riparian zone that provides nutrients to the stream ecosystem.
- Connected to it's floodplain and the terrestrial habitat.

Adapted from Bell et al. (2012)

Urban Stream Syndrome

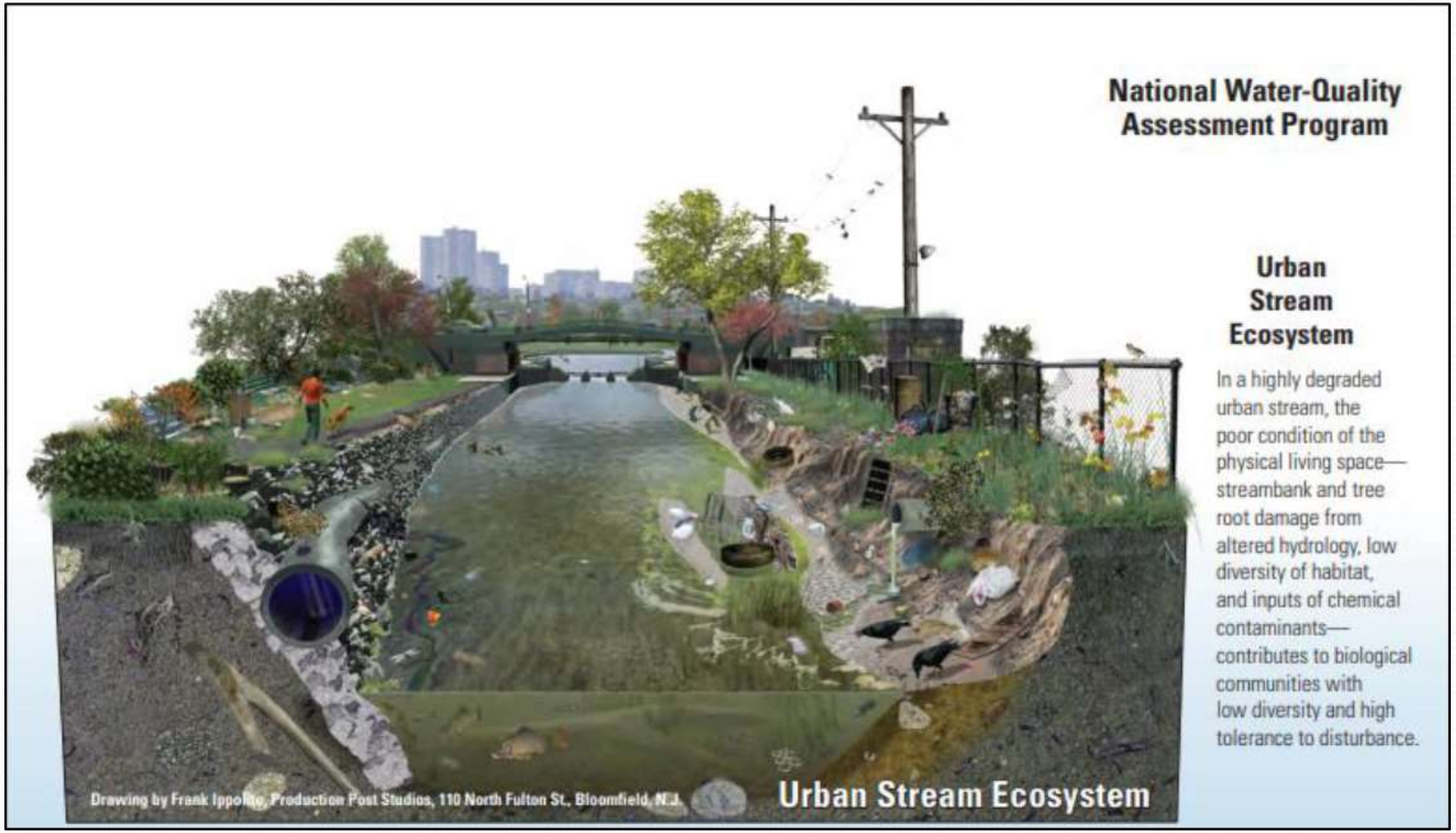
Stream habitat quality and benthic macroinvertebrate community diversity are negatively impacted by urbanization





Urban Stream Ecosystem

- Poor water quality; an unstable geomorphology with eroding banks; provides poor habitat.
- Altered hydrological regime; reduced the baseflow conditions; flashy stormwater runoff.
- Riparian zone is often thinned or non-existent; Primary food source shifts from terrestrial to algal sources.
- Disconnected from its floodplain.
- Watershed managers respond to urban stream degradation by repairing degraded streams using stream restoration techniques.



Adapted from Bell et al. (2012)

General Research Focus

- I conducted three research studies designed to improve the understanding of how the increased stormwater from urban areas impacts the aquatic insect assemblages' taxa and trait richness and diversity.

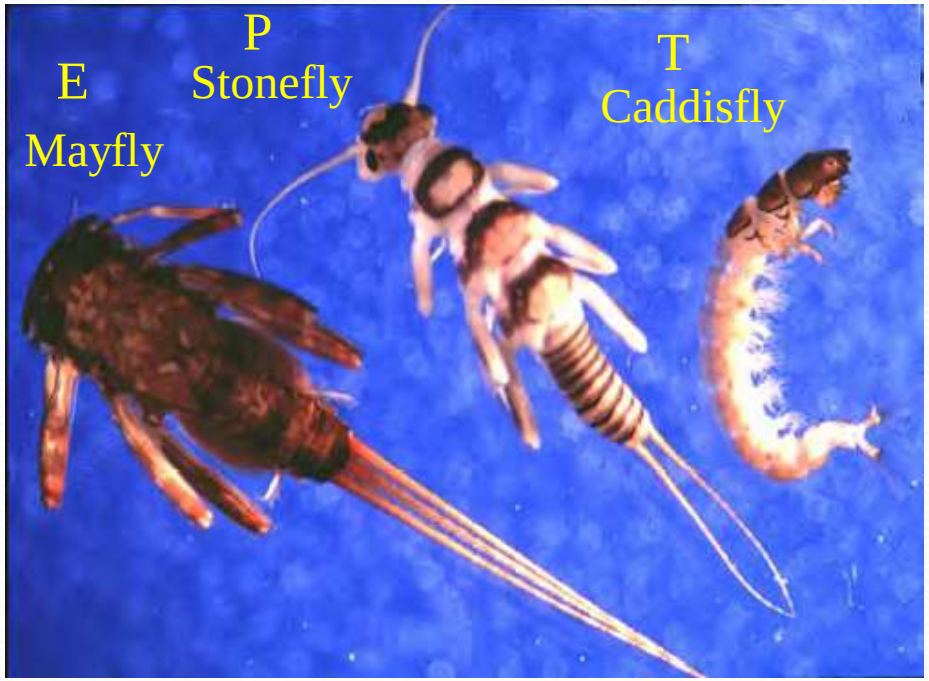
- *Impact of land use changes over a period of 26 years on benthic macroinvertebrate diversity and function in Piedmont streams in North Carolina*

- *Evaluation of the relationship between stream habitat quality and benthic macroinvertebrate taxa and trait richness and diversity in Piedmont streams in North Carolina*

- *Impact of stormwater on benthic macroinvertebrate diversity and stream ecosystem function in a Piedmont stream in North Carolina*

Benthic Macroinvertebrates

- Benthic macroinvertebrates include all organisms that live on or in the stream bottom that are large enough to see without a microscope and do not have a backbone.
- Most of the benthic organisms are aquatic insects.
- Other benthic organisms include worms and leeches, clams and mussels, snails, and crayfish.
- Benthic macroinvertebrates are useful as biological water quality indicators.

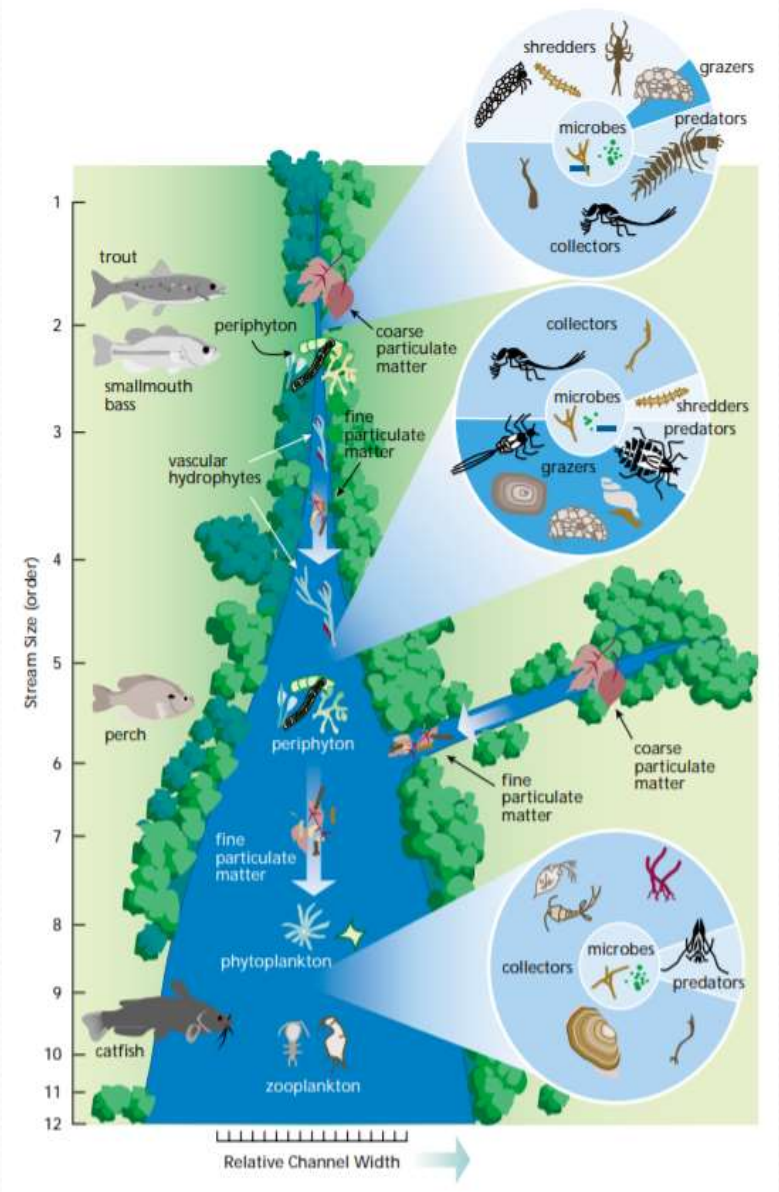


EPT Taxa – Photo by Eric Fleek NCDWR

Taxa Traits

- Taxa traits - characteristics unique to each species reflecting their position in the stream ecosystem.

- Aquatic insect **trait** categories include:
  - Life History – rate of development, adult life span
  - Mobility – crawling rate, swimming ability, flying strength
  - Morphology – shape, size, respiration strategy
  - Ecology – feeding, thermal, habit preferences

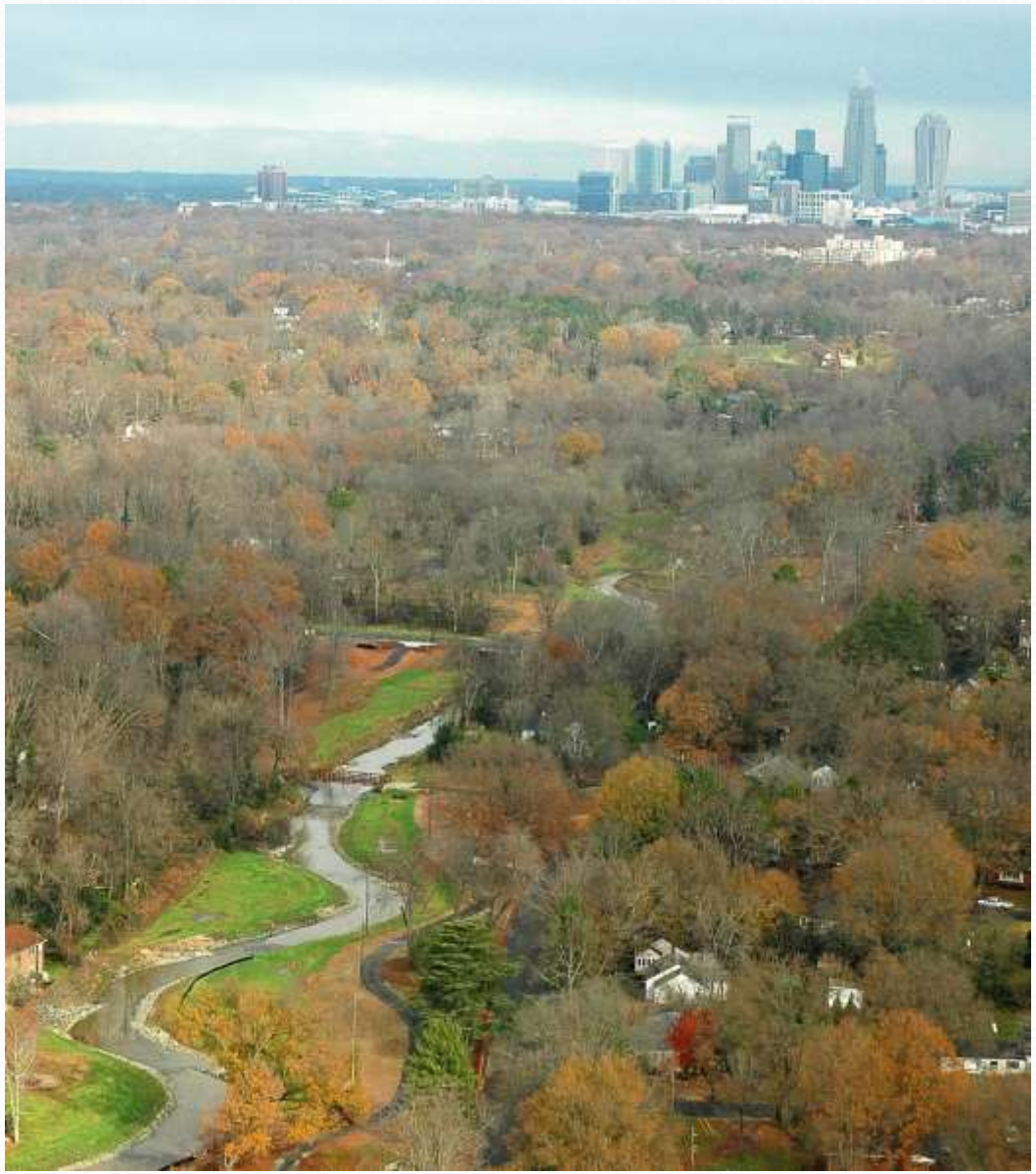


The River Continuum Concept (From Vannote et al. 1980)

Methods – Used in All 3 Studies

1. **Benthic Macroinvertebrates** collected using Standard Qualitative Method developed by North Carolina Department of Environmental Quality (NCDEQ) Biological Assessment Branch. Focus of all studies were on the aquatic insects.

1. **Stream Habitat Quality** measured using the Mecklenburg Habitat Assessment Protocol (MHAP). Based on EPA Rapid Bioassessment Habitat Assessment Protocols (2000).



Study 1. Impact of Land Use Changes Over a Period of 26 Years on Benthic Macroinvertebrate Diversity and Function in Piedmont Streams in North Carolina

- The Charlotte-Mecklenburg Storm Water Services (CMSWS) has been collecting benthic macroinvertebrate community data since 1994.

- This long-term data set provided the opportunity to study the impact of land use changes on biodiversity and ecosystem function in stream ecosystems in watersheds that span a gradient from rural to urban land use.

Research Questions

1. **How do EPT Taxa and Trait Richness and Diversity change with increases in percent IC?**

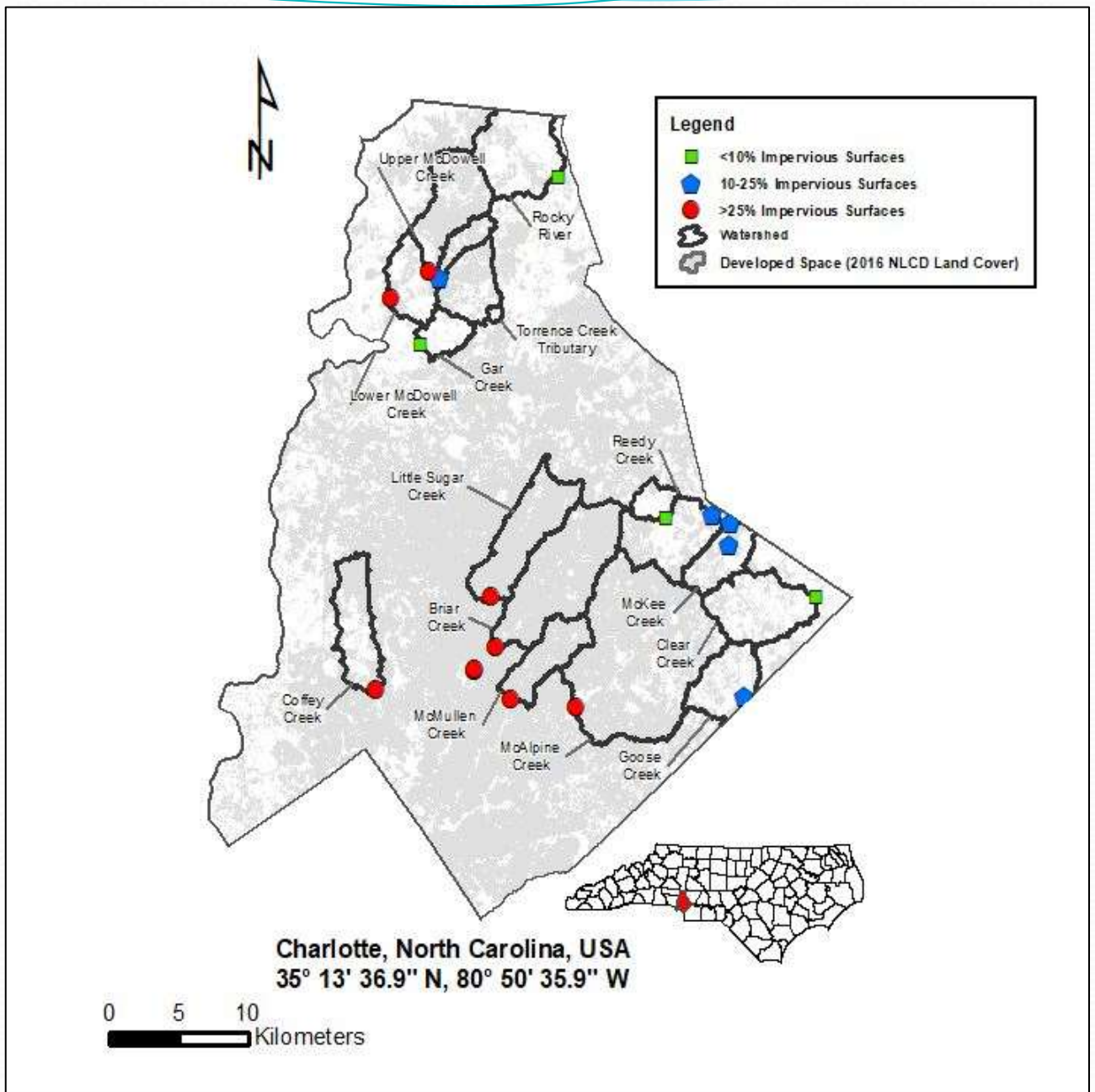
1. **How will individual taxa and traits respond to increases in percent IC?**

Study 1. Methods: Study Sites

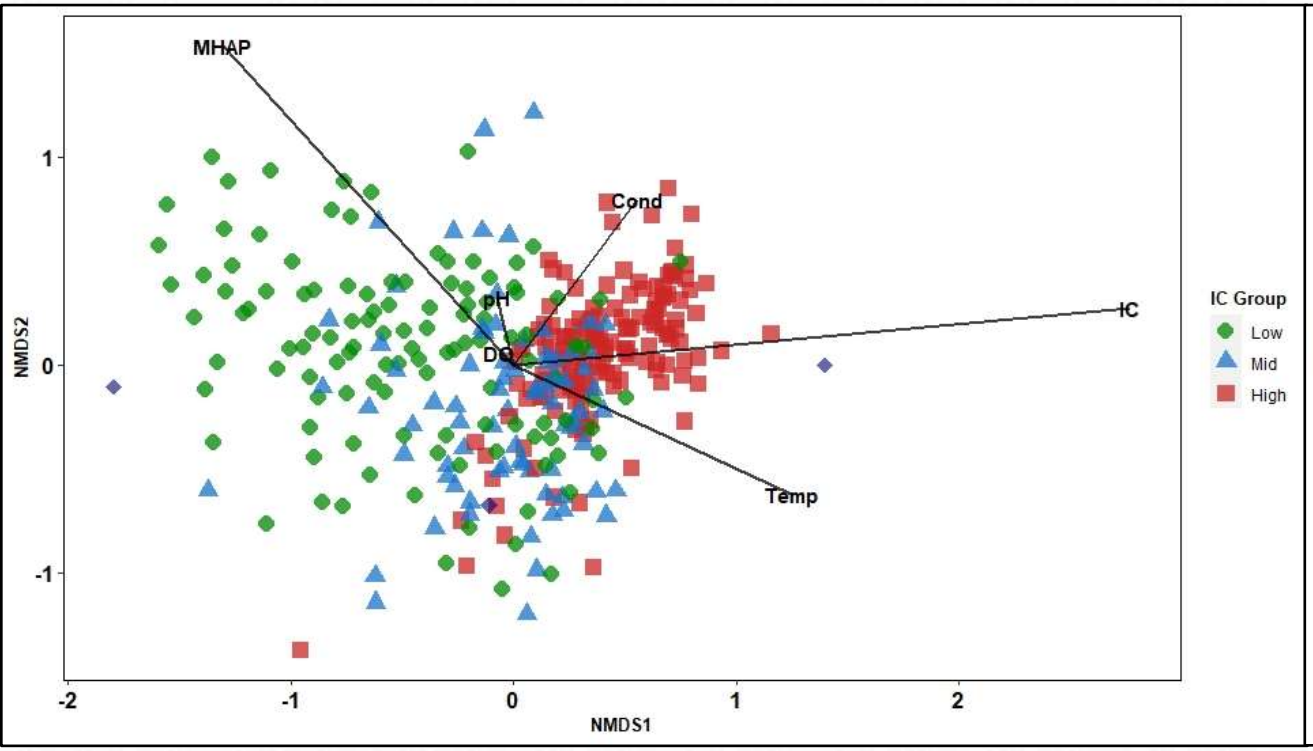
- Urban stream watersheds that span a gradient of % Impervious Cover:
  - Low (<10%; green)
  - Mid (10-25%; blue)
  - High (>25%; Red)
- Monitored annually since 1994

Additional methods:

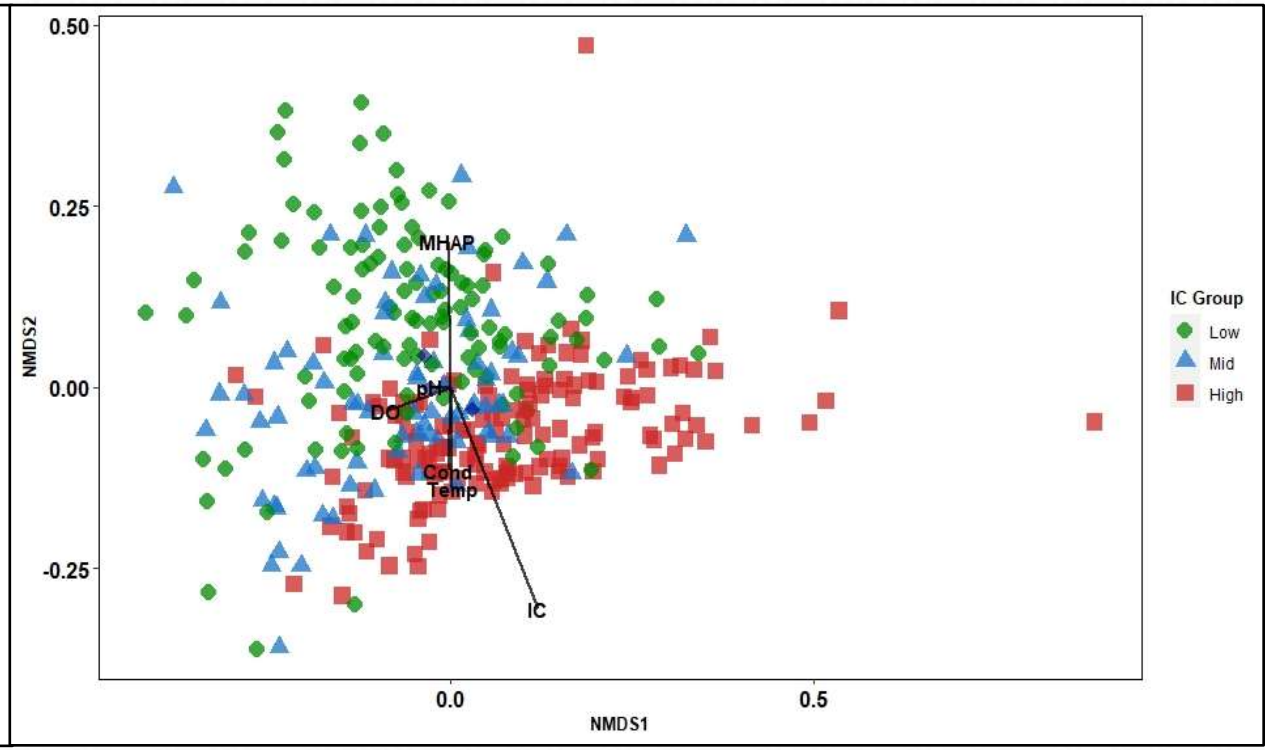
Hydrology - Daily flow data from USGS stream gage station located at each sampling site.



Question 1: EPT Taxa and Trait Assemblages in the Low %IC and High %IC Streams were Different

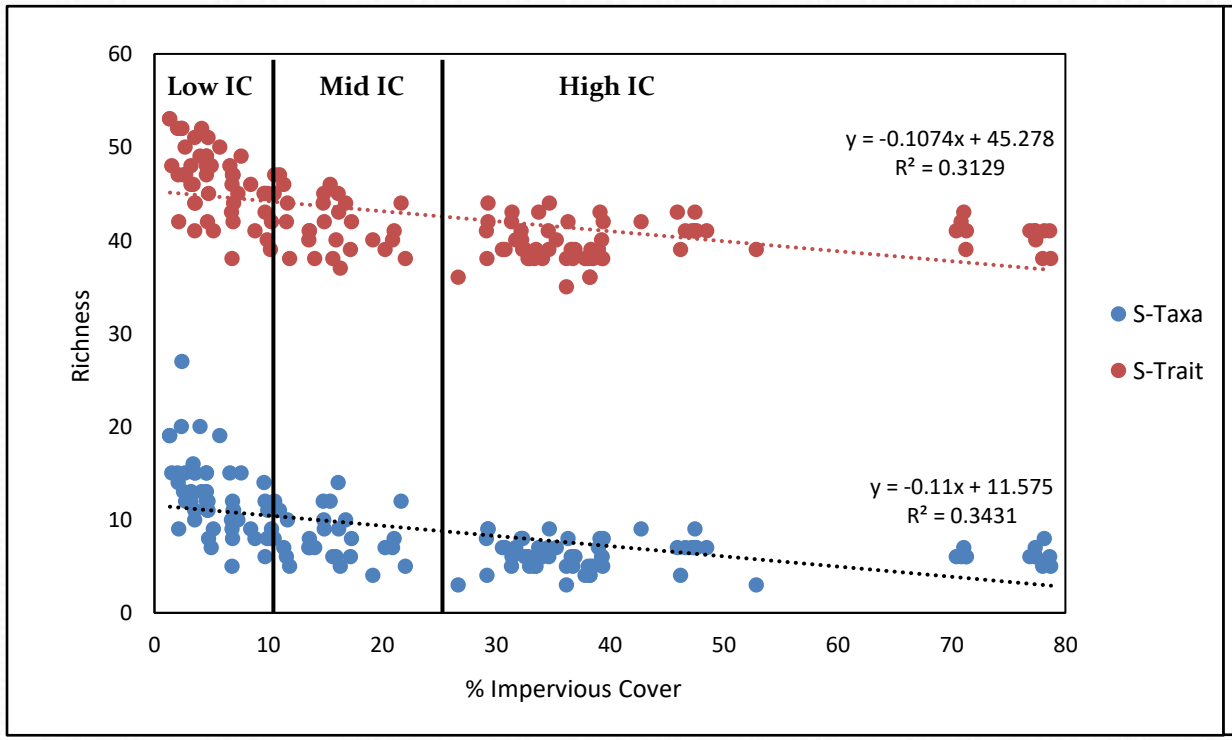


EPT Taxa

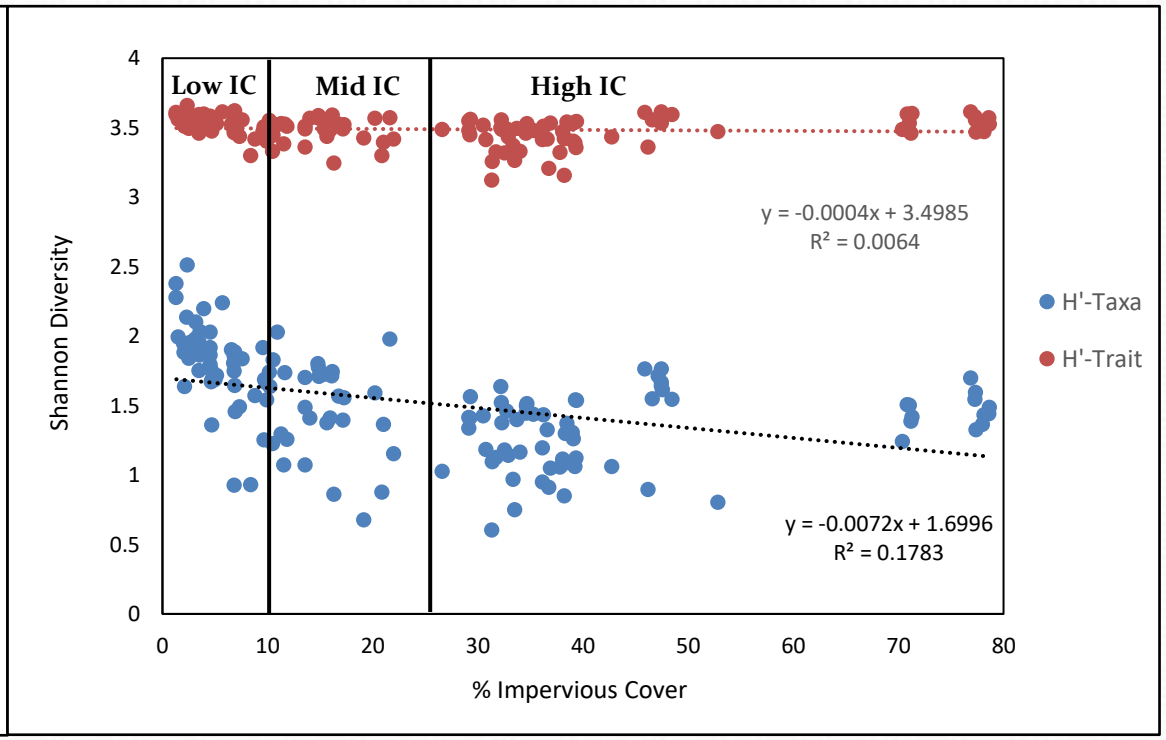


EPT Trait

Question 1: EPT Taxa Richness and Diversity Declined at a Significantly Higher Rate with Increases in Percent IC than Trait Richness and Diversity

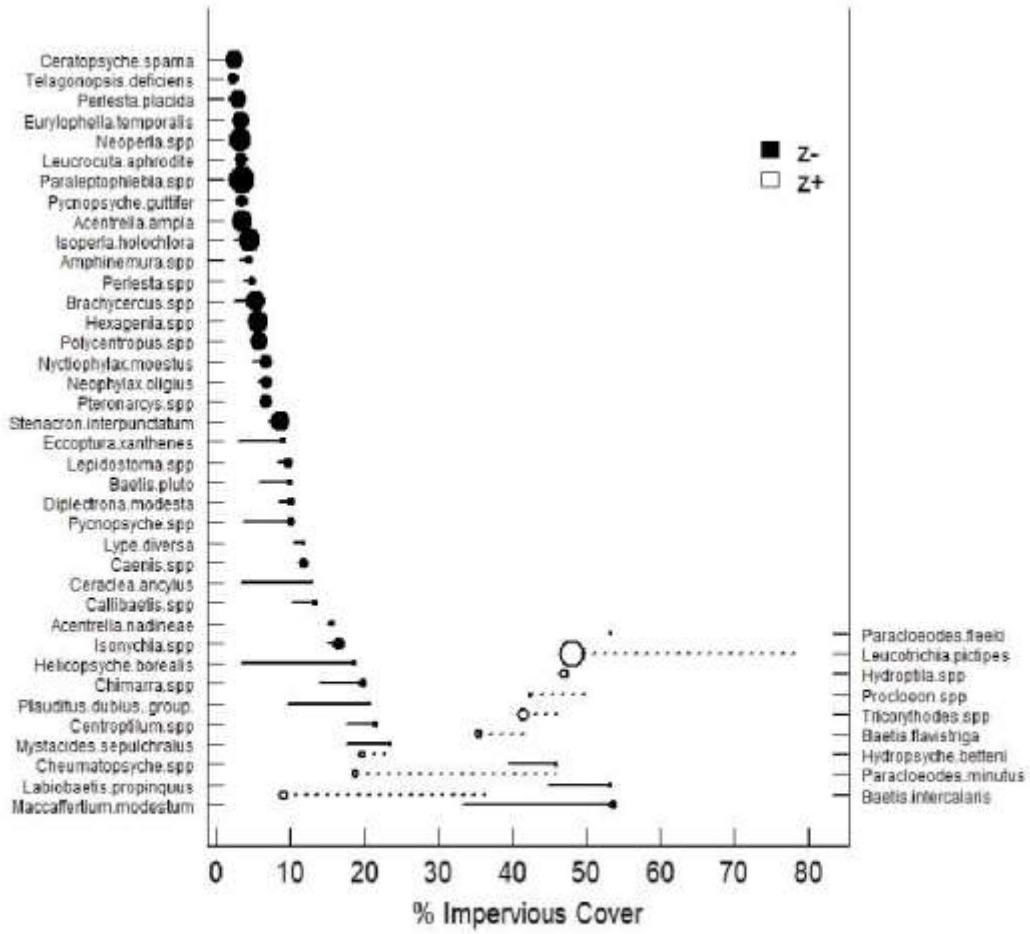


Richness

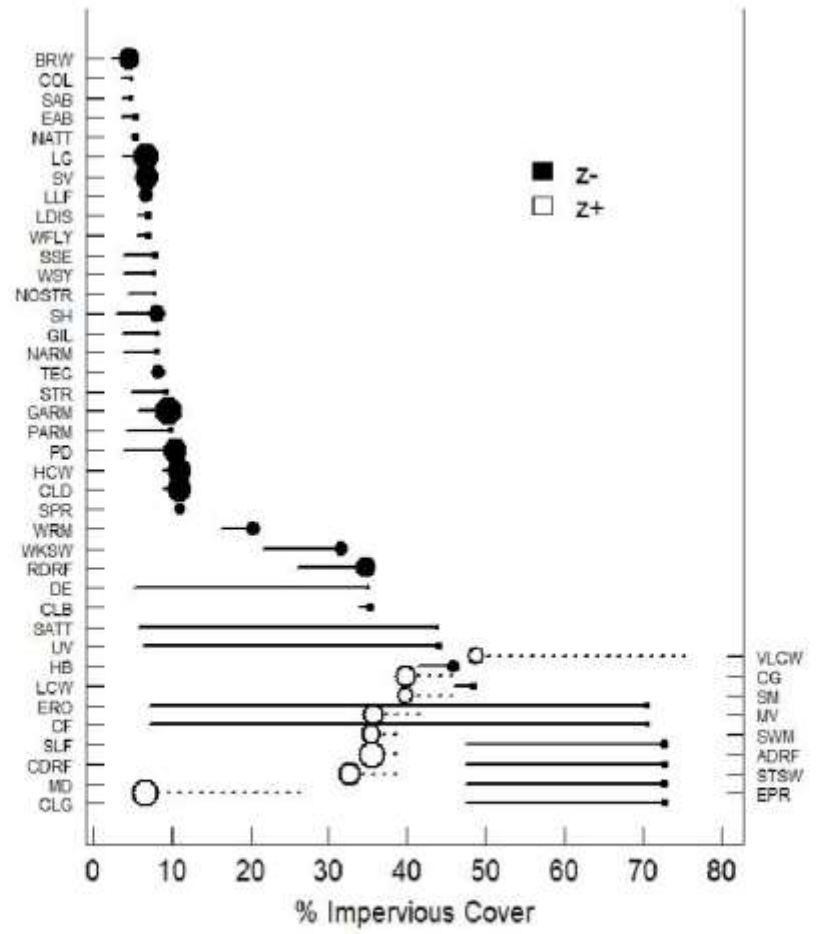


Diversity

Question 2: Threshold Indicator Taxa Analysis (TITAN) for Taxa and Trait Richness by Percent Impervious Cover



Taxa



Trait

Study 2. Evaluation of the Relationship Between Stream Habitat Quality and Taxa and Trait Richness and Diversity in Piedmont Streams In North Carolina

- A diversity of **habitats** with heterogeneous substrates is important for a stream to support a high diversity of aquatic macroinvertebrates.

Research Questions

1. **How do taxa and trait richness and diversity respond to decreases in stream habitat condition?**

2. **How are taxa and traits distributed among the microhabitats found in streams?**

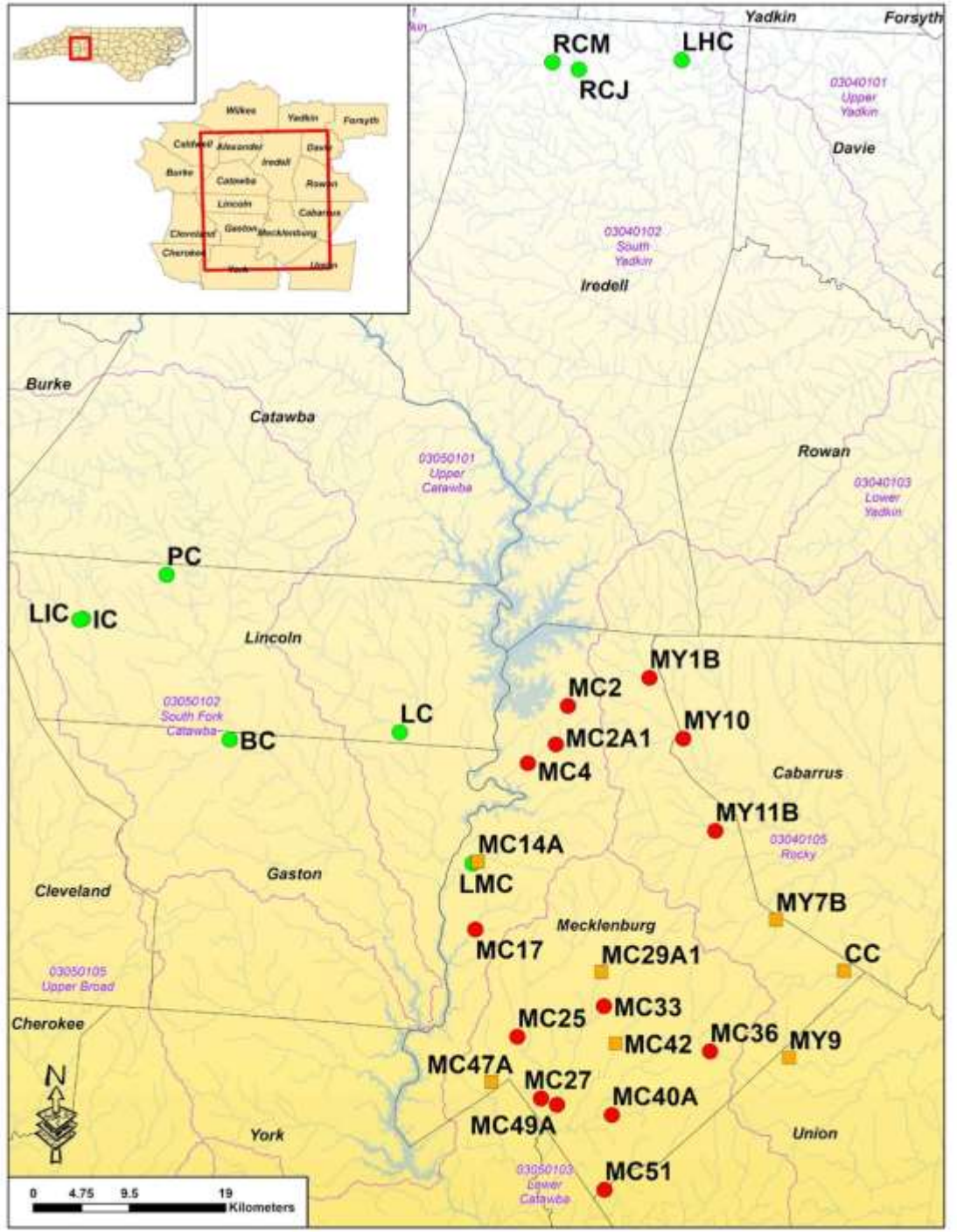
Study 2. Methods: Study Sites

- Rural and urban stream study sites in Mecklenburg, Lincoln and Iredell Counties in Piedmont North Carolina.

- *Stream Habitat Conditions*:
  - Supporting (green);
  - Partially Supporting (yellow);
  - Impaired (Red).

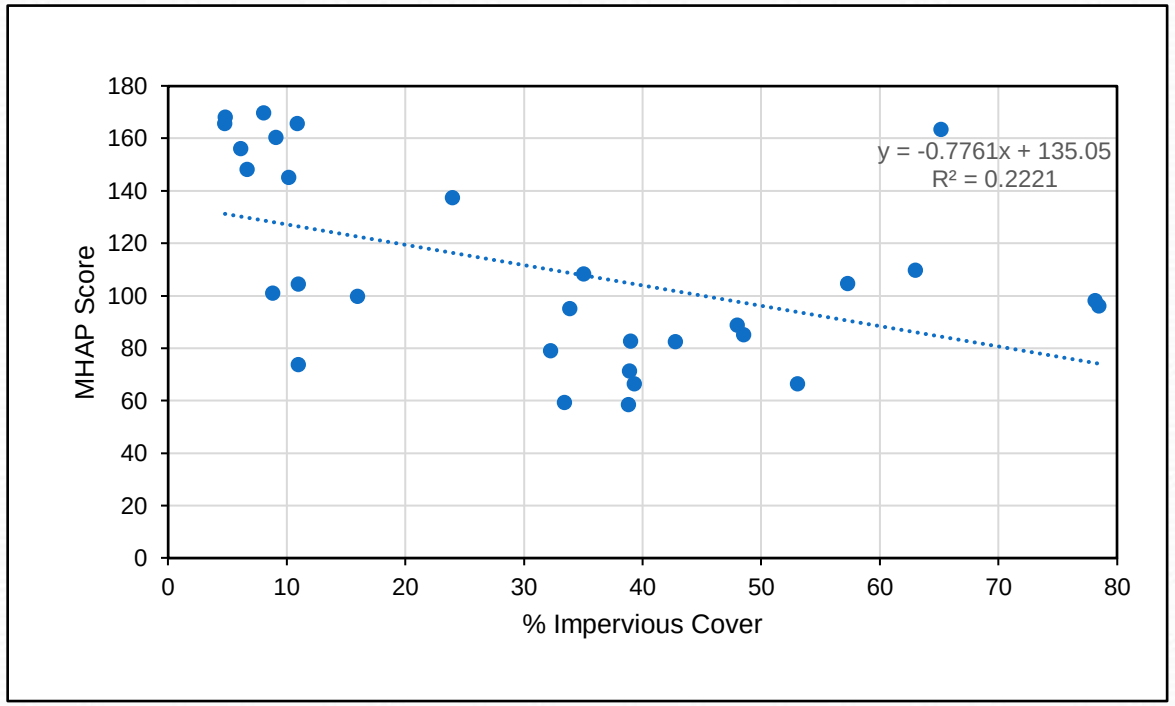
Additional methods:

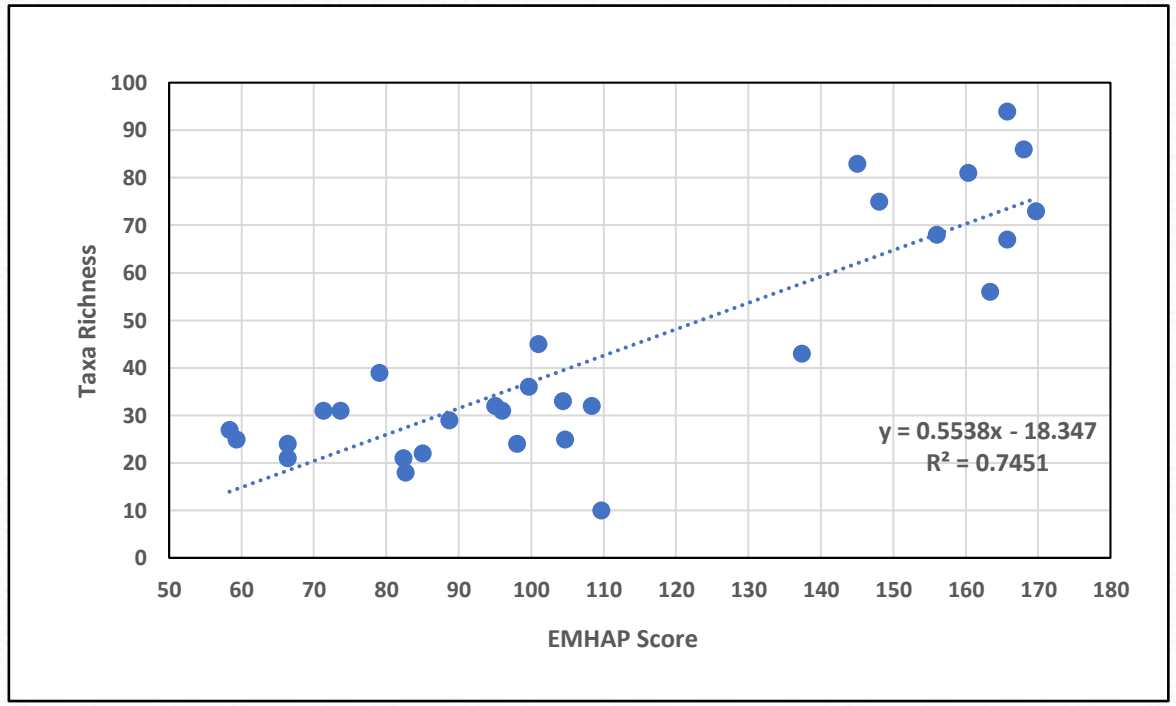
Microhabitat sampling - 7 microhabitats (Riffles, Root Wads, Undercut Banks, Leaf Packs, Woody Debris, Backwater Areas, and Sandy Areas) from the 10 streams with high quality habitats were sampled.



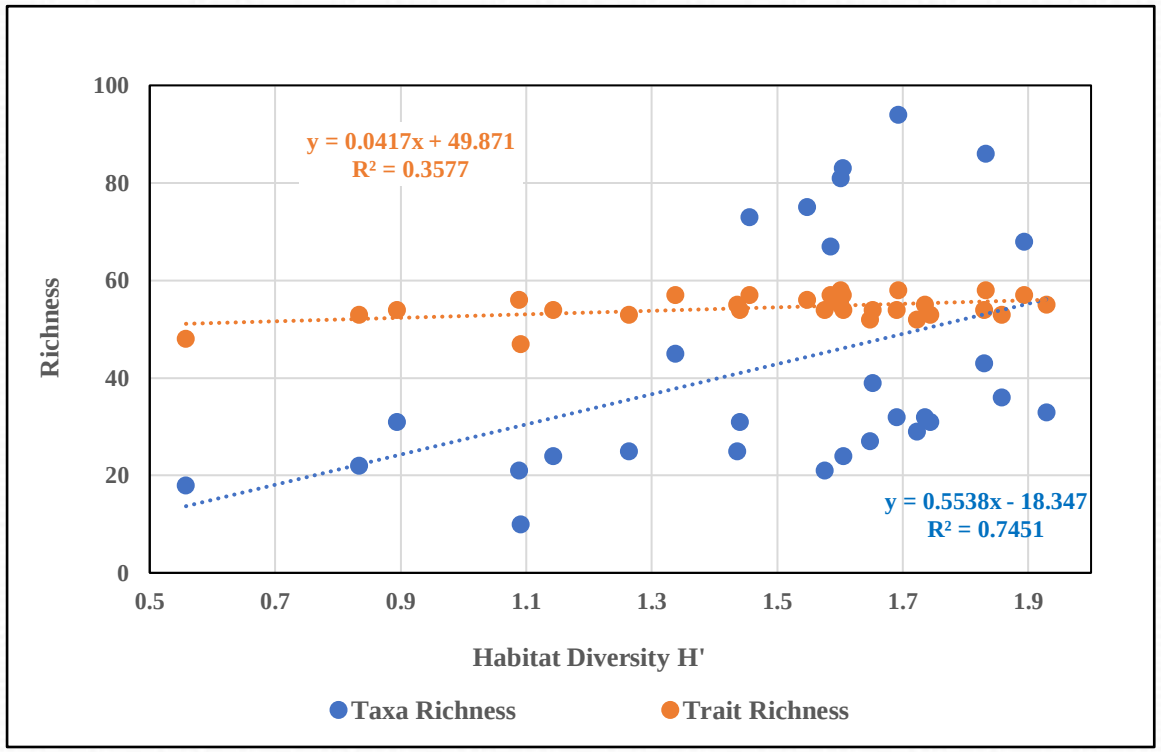
Relationship Between Stream Habitat Quality and Taxa Richness

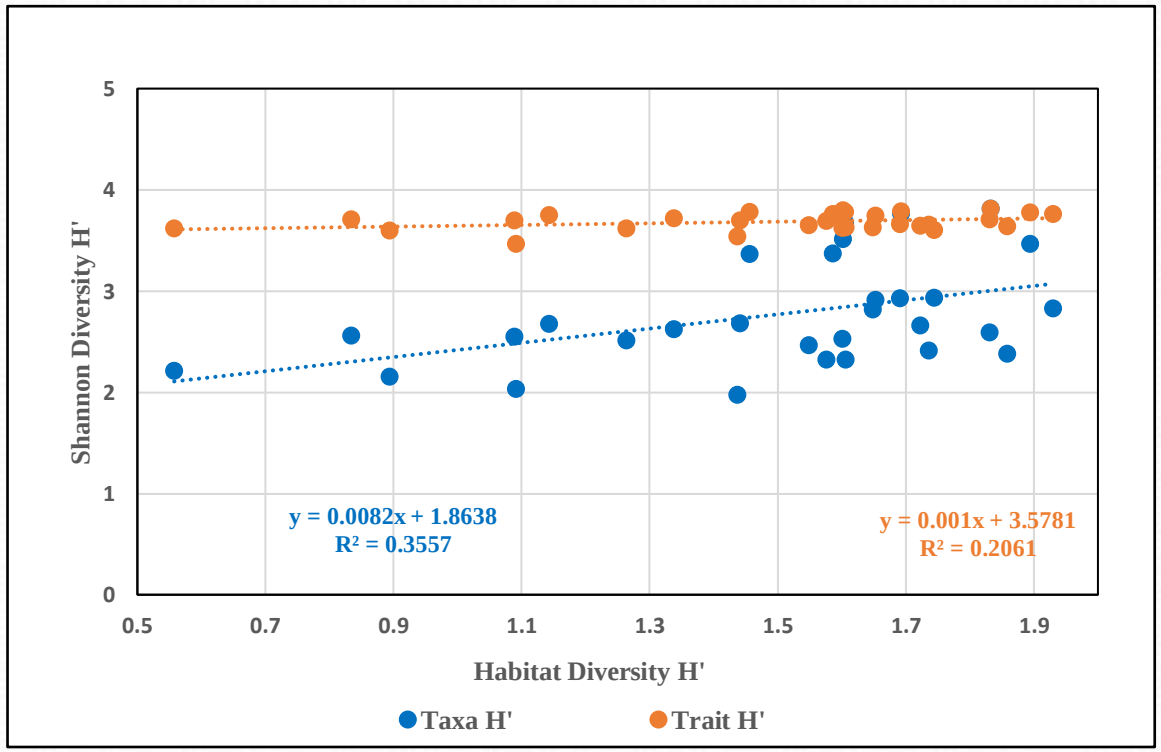
- Stream habitat condition has been shown to decrease with increases in percent impervious cover (%IC).



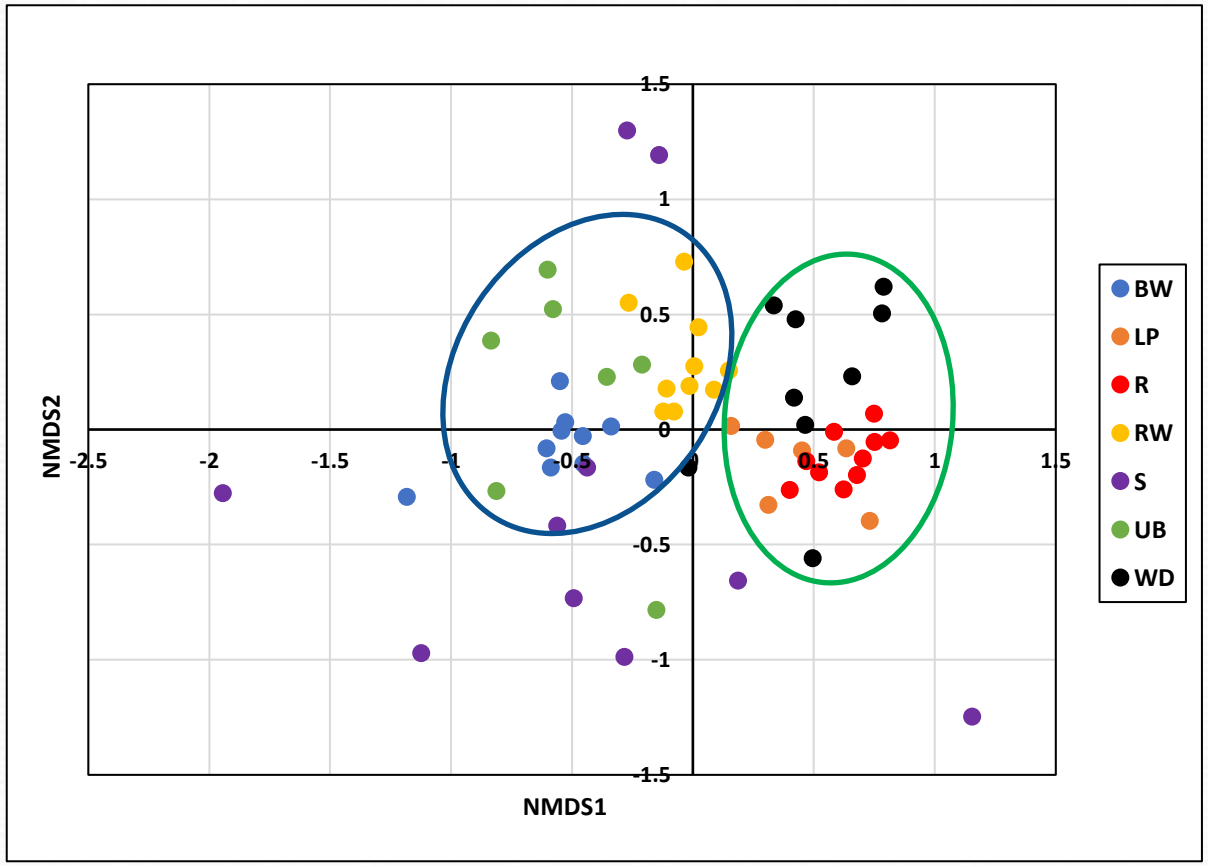


Question 1: Taxa Richness and Diversity Increased at a Greater Rate Than Trait Richness and Diversity Along an In-stream Habitat Diversity Gradient

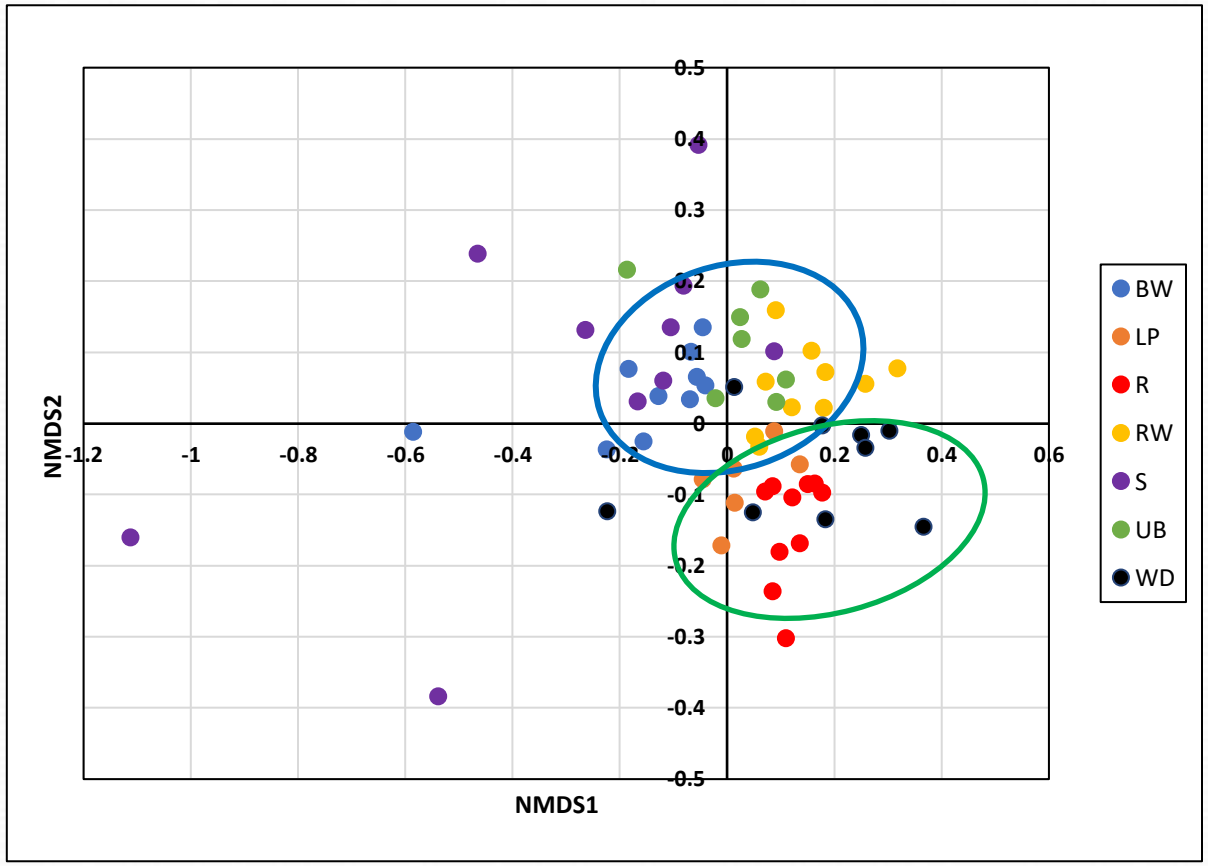




Question 2: The Taxa and Traits Found in Riffles, Leaf Packs, and Woody Debris Were More Similar Than Taxa and Traits Found in Backwater, Undercut Banks and Root Wads



Taxa



Traits

Study 3. Impact of Stormwater on Benthic Macroinvertebrate Diversity and Stream Ecosystem Function in a Piedmont Stream in North Carolina

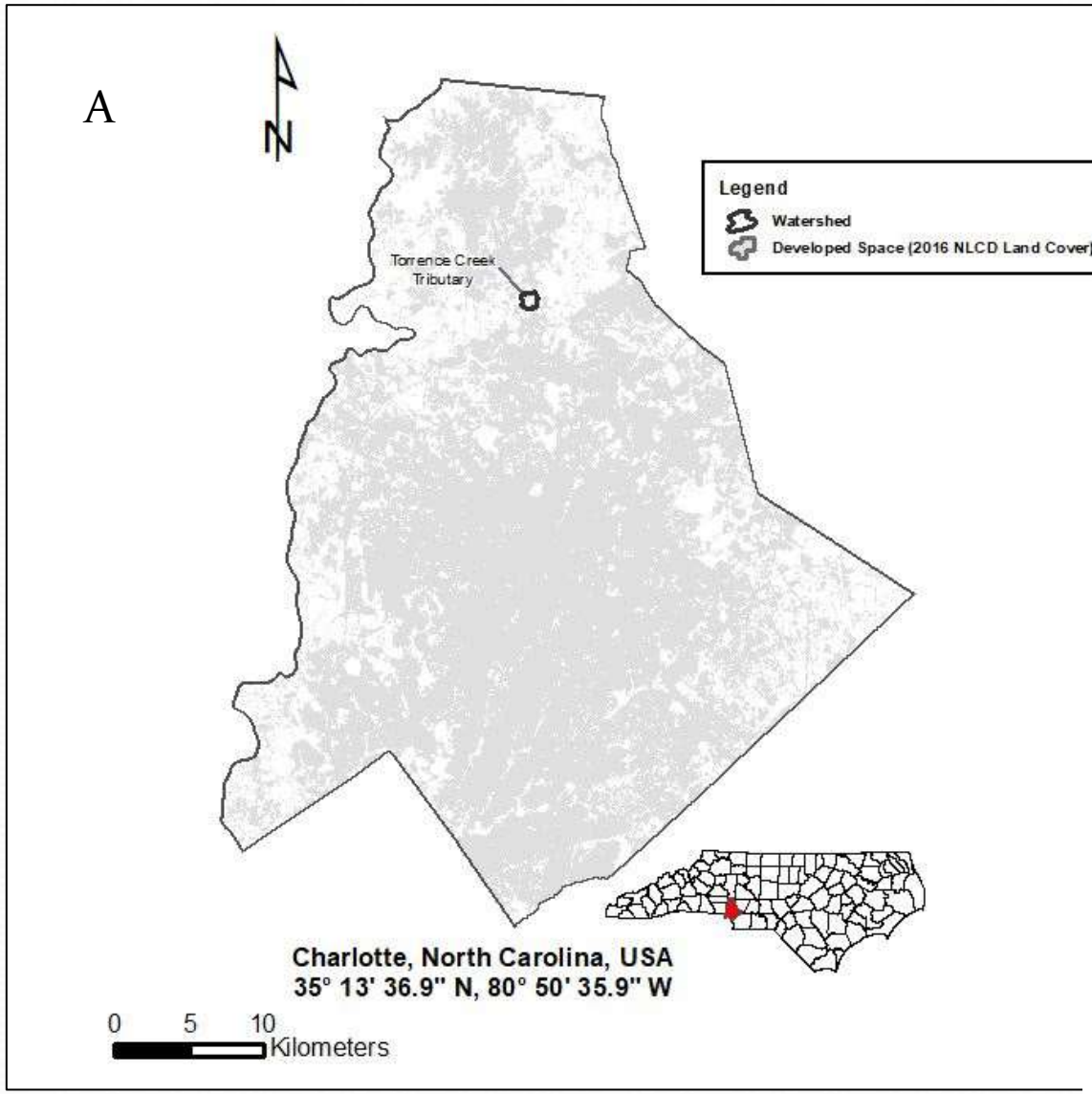
- I examined the impact of unmitigated stormwater runoff on stream channel hydrology, stream benthic macroinvertebrate taxa and trait richness and diversity, and on an urban stream food web.

- This study took advantage of a ***natural field experiment*** consisting of two adjacent tributaries that were similar in all aspects except stormwater. One tributary received stormwater from a residential development via storm drain infrastructure while the other tributary received stormwater via more natural overland and subsurface processes.

Research Question

How do the benthic macroinvertebrate taxa and trait diversity and richness patterns differ between 2 tributaries receiving stormwater from different sources?

Study 3. Methods: Study Sites



- **(A)** Torrence Creek Tributaries near Huntersville.
- **(B)** The stormwater impacted tributary (TI) is adjacent to a 200-home development and the forested tributary (TF) flows through a forest dominated watershed.

Study 3. Methods

In addition to benthic macroininvertebrate monitoring and MHAP assessment:

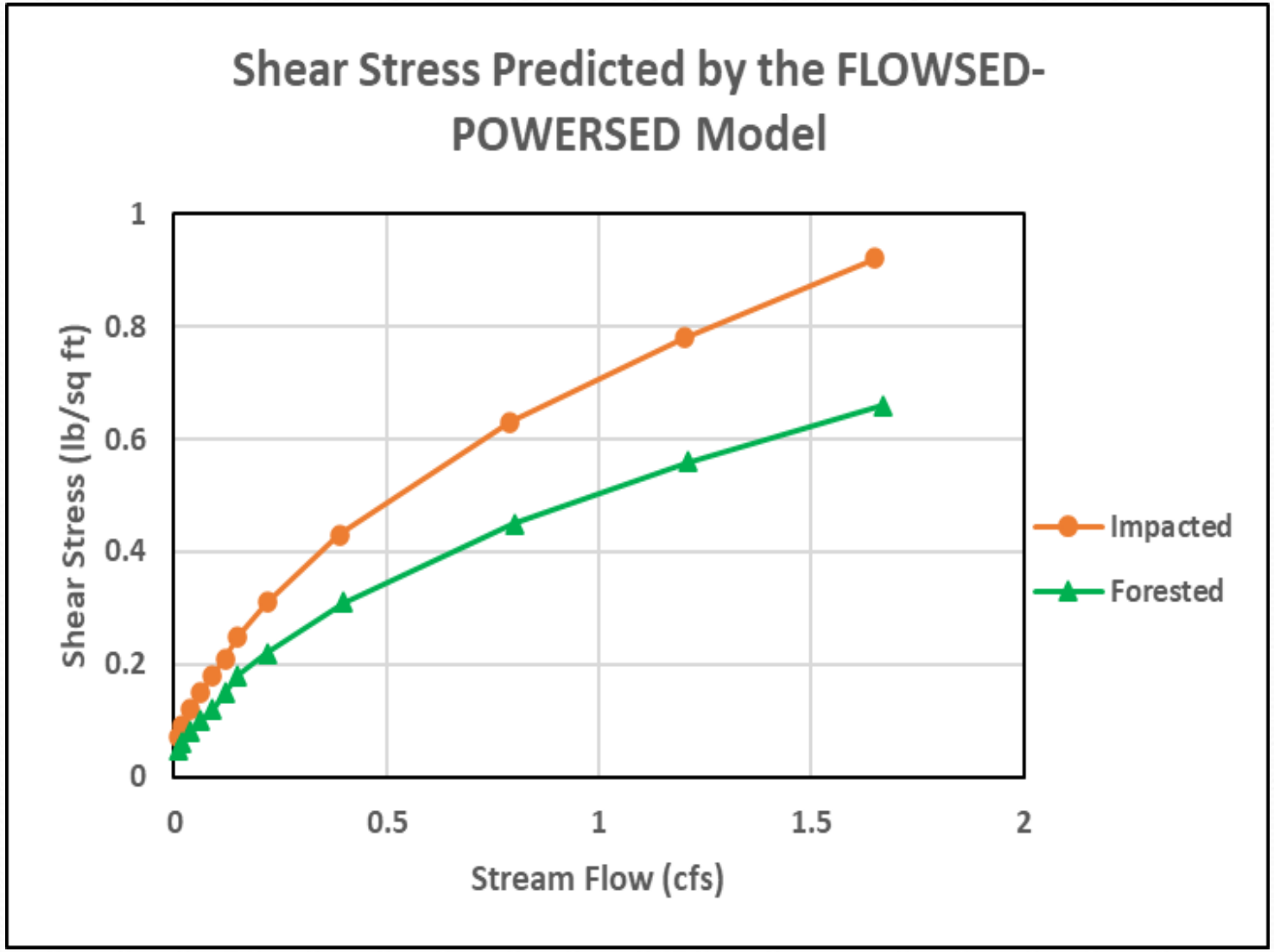
Channel Geomorphology and Hydrology Assessment

a. Charlotte-Mecklenburg County Stormwater Services (CMSWS) survey the channel geomorphology of each tributary in July 2016.

a. The 100-particle Wolman pebble counts were conducted in February 2018 in a representative riffle at sites TF1 and TI1.

a. The sediment transport capacity of each tributary was modeled by CMSWS using the FLOWSED-POWERSED model in the RIVERMorph software (Version 5.2.0; Stantec, 2021).

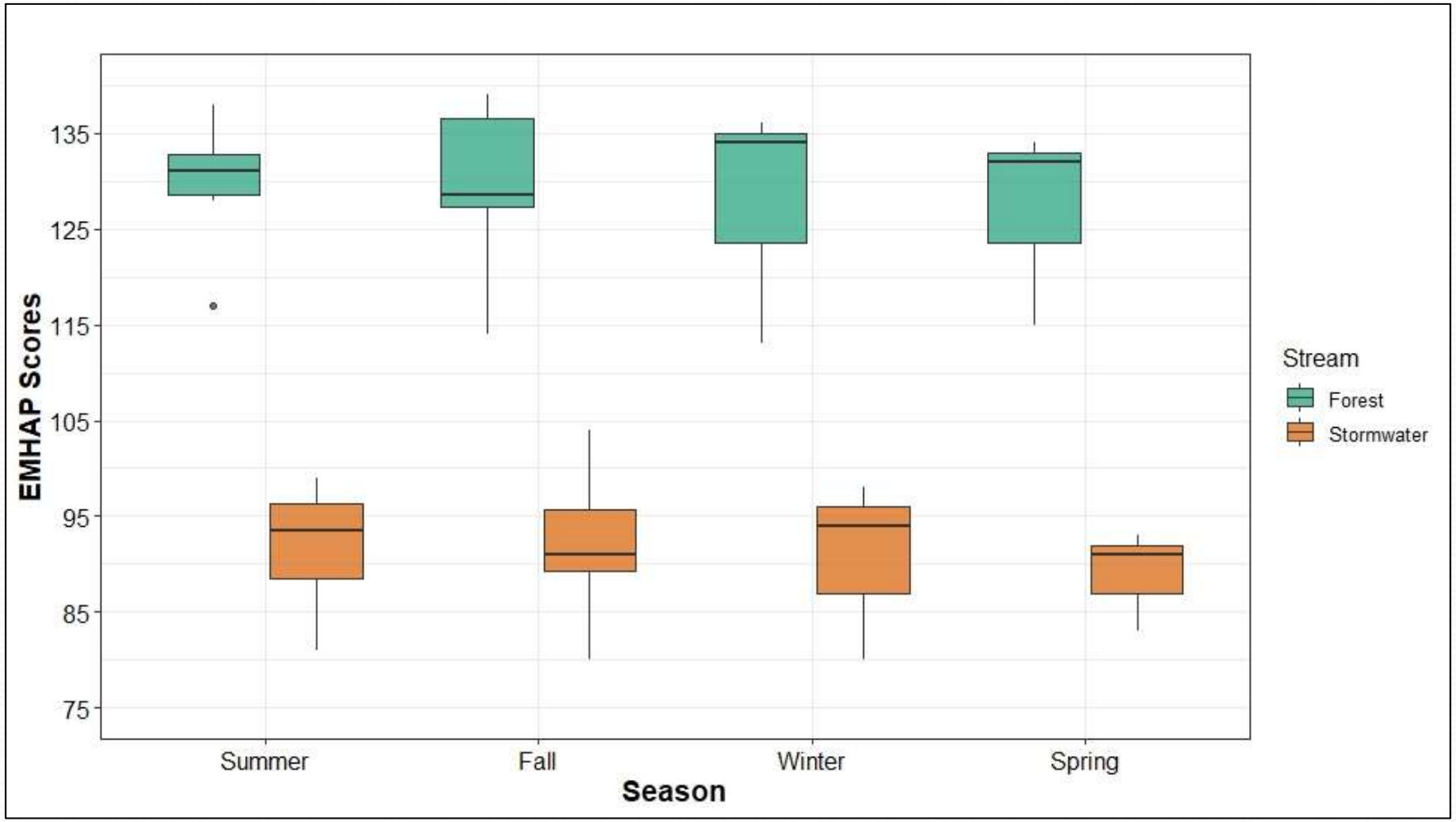
Question 1: FLOWSED-POWERSED model results



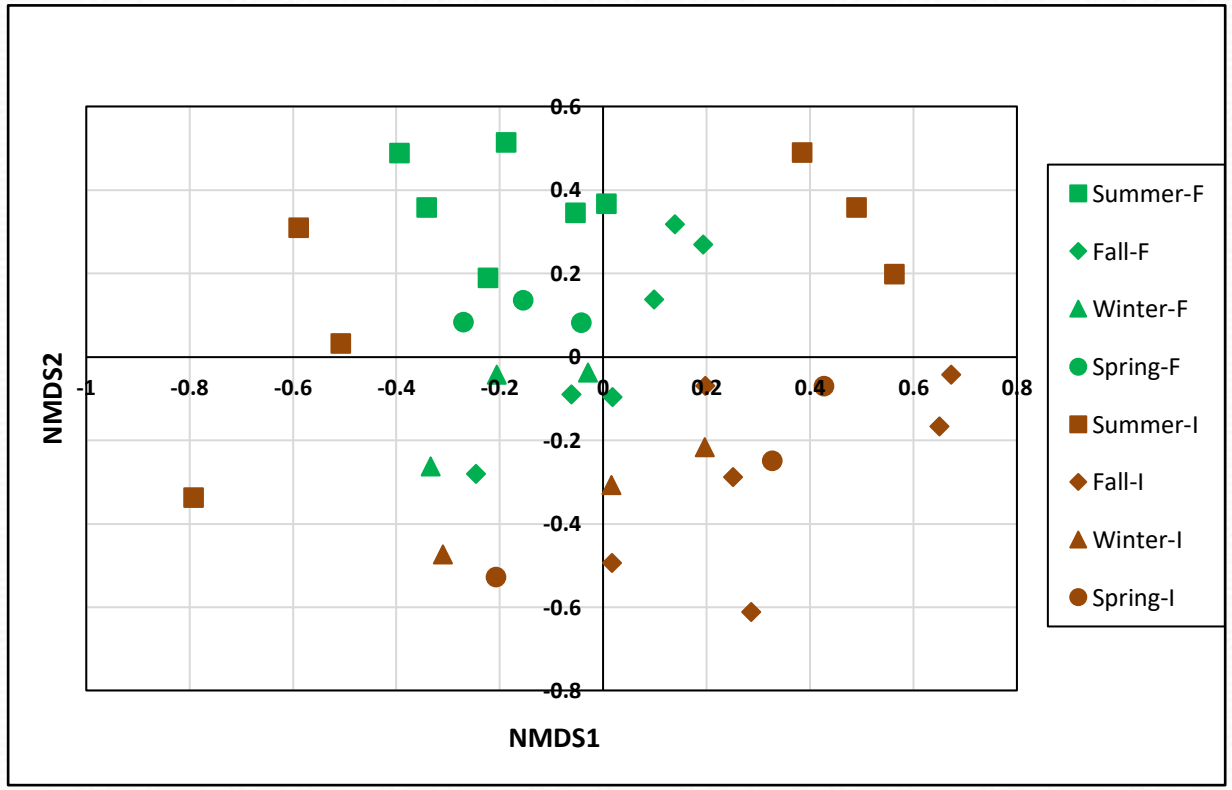
- FLOWSED-POWERSED model predicted that Shear Stress is greater in the stormwater impacted (brown) tributary than the forested (green) tributary for the same bankfull event.

- The d_{50} particle size in the TI tributary was 18 mm smaller (14 mm) than the d_{50} in the TF tributary (32 mm).

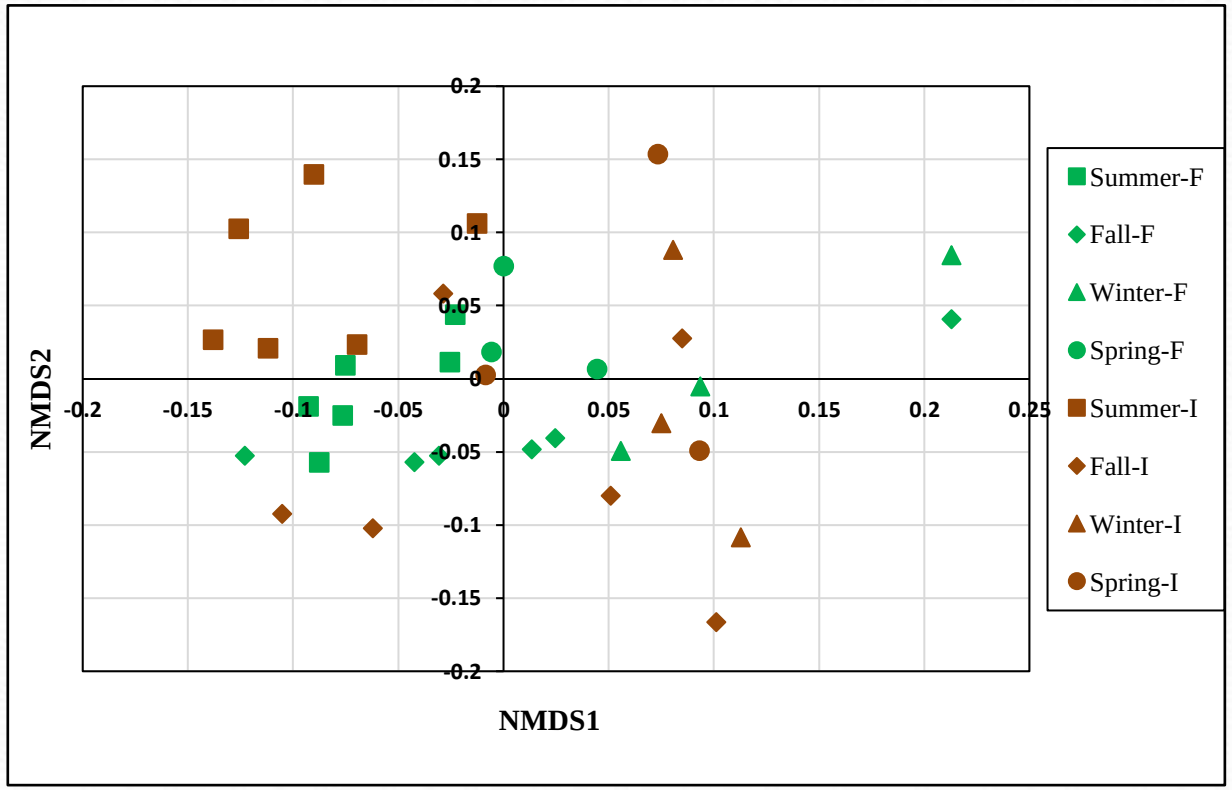
Question 1: The stream habitat was significantly higher in the forested tributary than in the stormwater impacted tributary



Question 1: Taxa and Trait Assemblages were Distinctly Different Between the Forested and Stormwater Impacted Tributaries



Taxa



Traits

Key Points of My Research

1. My first study, *Impact of land use changes on benthic macroinvertebrate diversity,* demonstrated that the impact of development (%IC) is directly related to declines in EPT taxa and trait richness. The decrease in taxa richness reflects loss of sensitive taxa and increases in tolerant taxa resulting in specific taxa and traits associated with categories of land use by percent impervious cover.

1. My second study, *Stream Habitat Quality and Taxa and Trait Richness and Diversity,* illustrated the importance of a stream having a heterogeneous habitat to support a highly diverse benthic macroinvertebrate assemblage.

1. My third study, *Impact of Stormwater on Benthic Macroinvertebrate Diversity and Stream Ecosystem Function*, demonstrates the direct impact that unmitigated stormwater has on benthic macroinvertebrate assemblages.

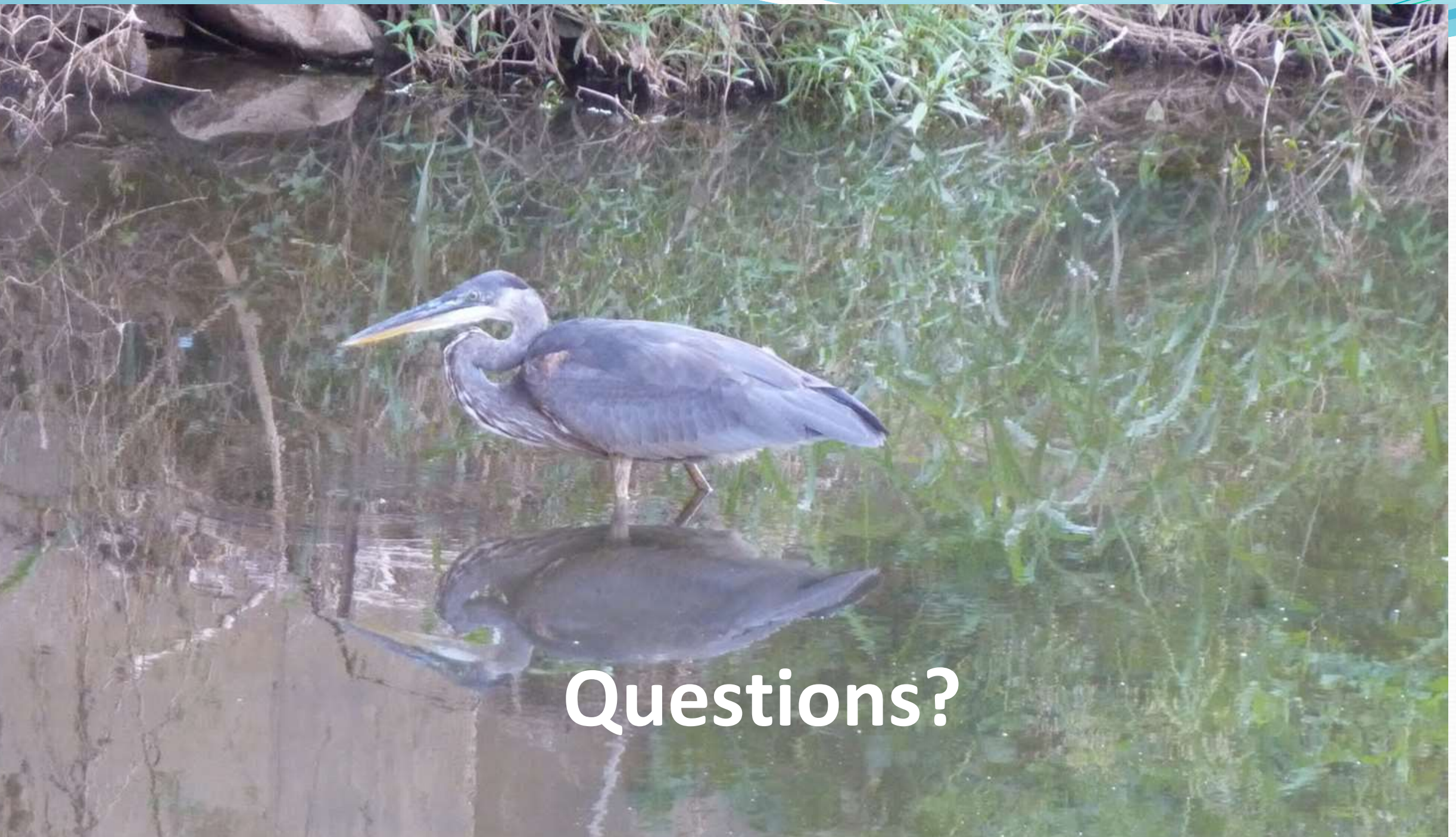
Implications For Stream Restorations

My results demonstrates the need to improve restoration design to restore the benthic macroinvertebrate community in urban streams:

a. Addressing the sources of hydrologic alterations as part of a stream restoration plan may lead to more successful restoration of an urban stream aquatic ecosystem.

a. Increasing diversity of stream habitats enhanced by restoration from primarily riffle-pool structures and woody debris to include undercut banks, root wads, back water areas, and structures that promote leaf packs.

a. Expanding the habitat improvement designs that currently focus primarily on the larval aquatic insect stage to include habitats required by the adult aquatic insects may resulting in self sustaining improved aquatic insect communities.


Questions?

Acknowledgements

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  - Ebenezer Gujjarlapudi, LUESA Director; Dave Canaan, retired Storm Water Services Director; and Rusty Rozzelle, Water Quality Program Manager
  - Additional thanks go out to:
    - Olivia Edwards, Environmental Supervisor: provided that necessary nudge to keep me going.
    - Josh DeMaury, Environmental Coordinator: created the site maps used in this dissertation and modeled the shear stress of the 2 Torrence Creek tributaries.
    - Matthew Phillips, Environmental Specialist II: was always willing to assist with data collection.
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