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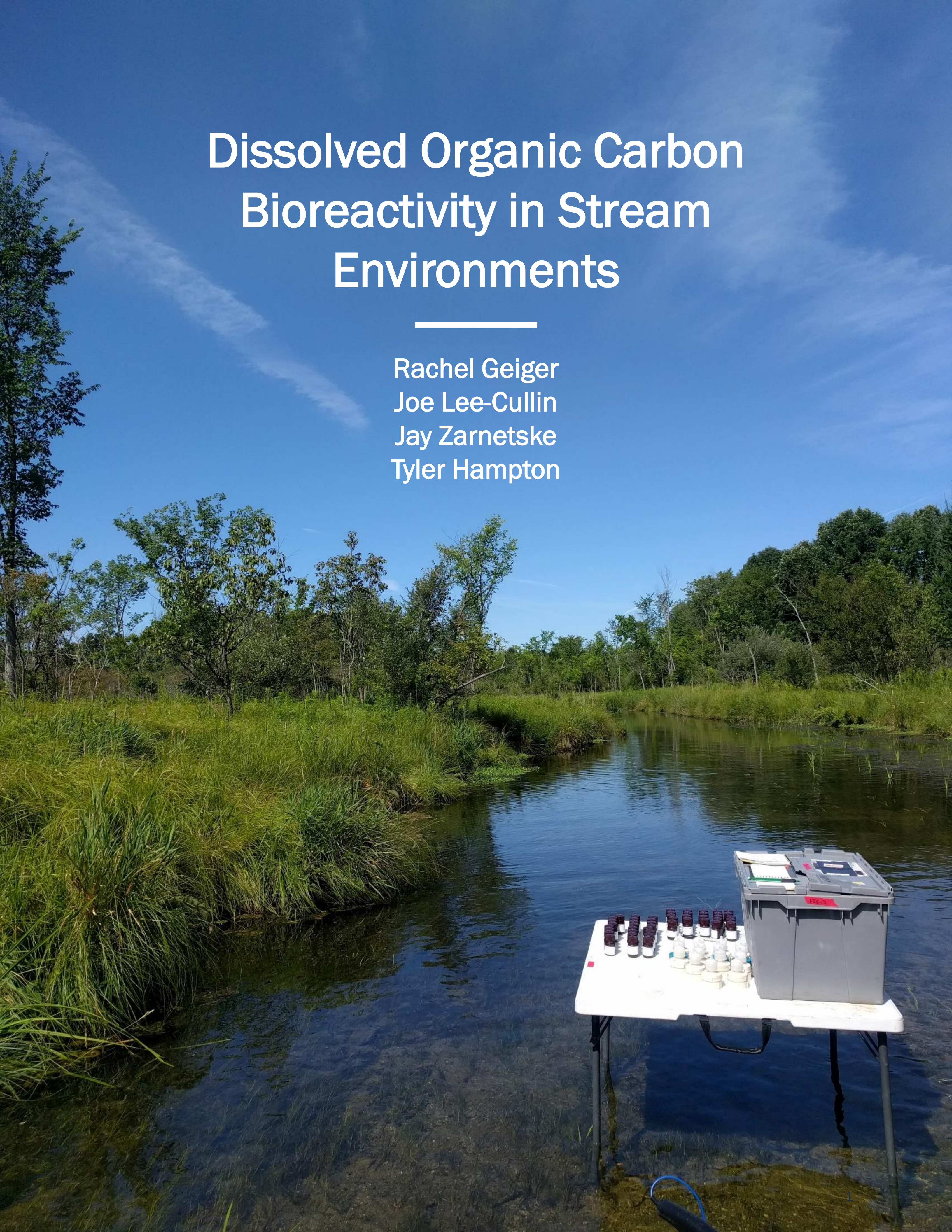
Dissolved Organic Carbon Bioreactivity in Stream Environments

Rachel Geiger
Western Washington University

Joe Lee-Cullin
Michigan State University

Jay Zarnetske
Michigan State University

Tyler Hampton
Michigan State University



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INTRODUCTION

My path through science education has been driven by the connections that I have found between the indoor and outdoor classrooms. Squishing a pile of soil through your fingers produces a different memory than memorizing a list of terms, although both are often have helped me advance through the education system. I have been lucky enough to participate in biogeochemical research in my field and delve into heart of academic discovery. This experience has continued to refine my identity as a scientist. At the root of my scientific pursuits there has always been a desire to share my knowledge and excitement about the natural world with others. My intention in this project is to convey my scientific research to a broader audience in order to make science, research, and biogeochemical cycling more accessible, regardless of academic background. I will take you on a journey from a large to small scale in order to examine the importance of dissolved organic carbon in aquatic environments and reflect on the importance of undergraduate research in freshwater science.

Enjoy!

Rachel Geiger
Environmental Science

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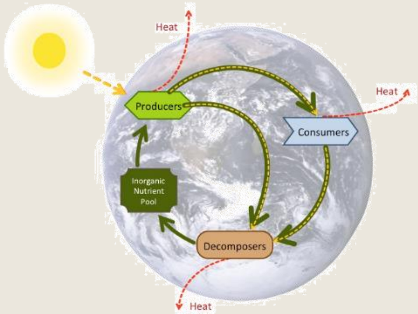
Why Dissolved Organic Carbon Cycling matters

Dissolved organic carbon (DOC) controls **energy transfer, biogeochemical cycling,** and **water quality** in surface and subsurface waters

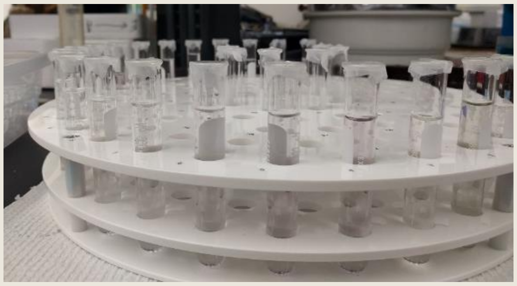
(Dophiede and Lewis)

- **Energy transfer** - includes processes like metabolism and photosynthesis



(Khan Acadamy)

- **Biogeochemical cycling** - the cycling of nutrients including carbon, nitrogen, and phosphorous in the environment



(Geiger)

- **Water quality** - the characteristics of water, often held to a specific standard

Objectives

❖*Unearth the **importance of DOC** in aquatic environments*

❖*Examine trends in **DOC degradation** through lab and field studies*

❖*Reflect on the **importance of undergraduate research** in freshwater science*

The Project

I participated in research outside of Western Washington University. This experience was grounded in more acronyms than most scientific papers, yet it is in these acronyms that I found context and funding for my project.

NSF	National Science Foundation
KBS	Kellogg Biological Station
LTER	Long Term Ecological Research
REU	Research Experience for Undergrads
@	
MSU	Michigan State University

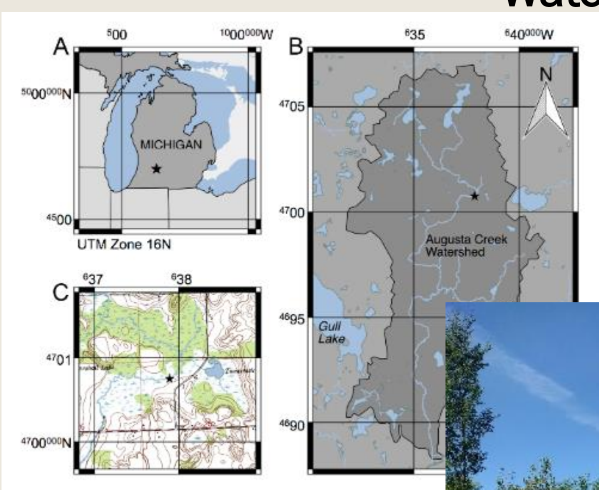
KBS LTER
Kellogg Biological Station
Long-term Ecological Research

MSU Watershed Science and Hydroecology Lab

The Scale

This project exists at a very small scale, but in order to comprehend the molecular level it is important to understand the larger context of the aquatic stream ecosystems. From a state, to a watershed, to a stream, to a tree, to a leaf, to a carbon structure, there is a nested order to these ecosystem structures.

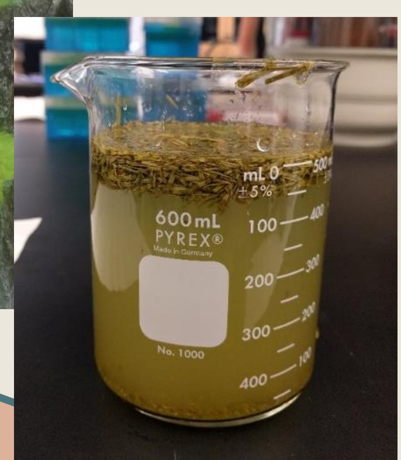
Watershed



Stream

Leaf/carbon source

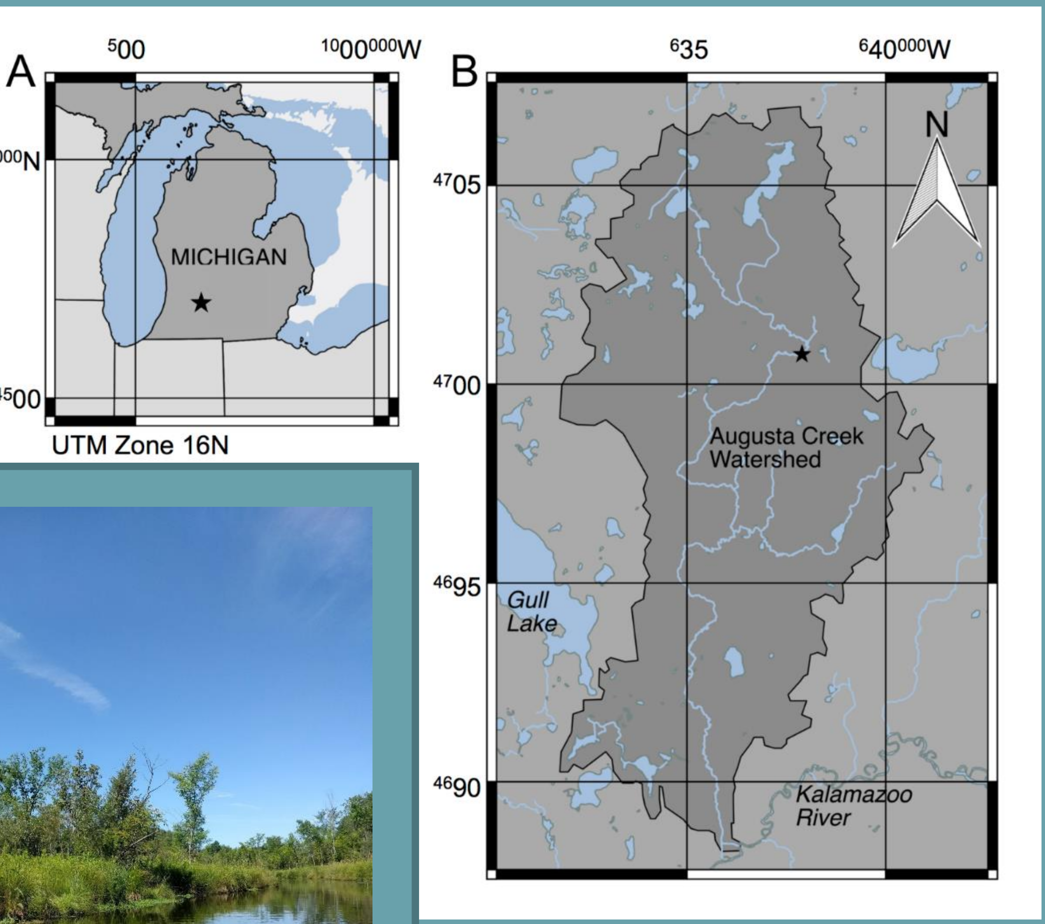
DOC



LARGE → small

Study Site

The study site for our research was Hickory Corners, Michigan, located in the Augusta Creek Watershed. This watershed is the area of land that drains into our model stream of Augusta Creek. Augusta Creek is a second order stream that was formed from two smaller first order, headwater streams joining together.



Carbon Sources

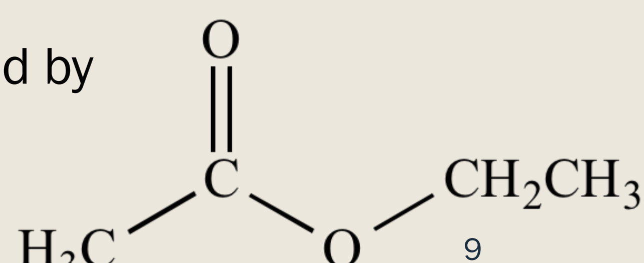
Carbon can enter the stream from many different sources in a riparian ecosystem. In this study, we focused on the two different tree species that contributed leaves into Augusta Creek, as well as a carbon source found naturally in the stream called flocculent material (floc). These carbon sources were compared acetate which was used as a simple, uncomplicated form of carbon used as a control.

- **Elm** (*Ulmus spp.*) - deciduous species found on the banks of Augusta Creek

- **Tamarack** (*Larix laricina*) - coniferous species found on the banks of Augusta Creek

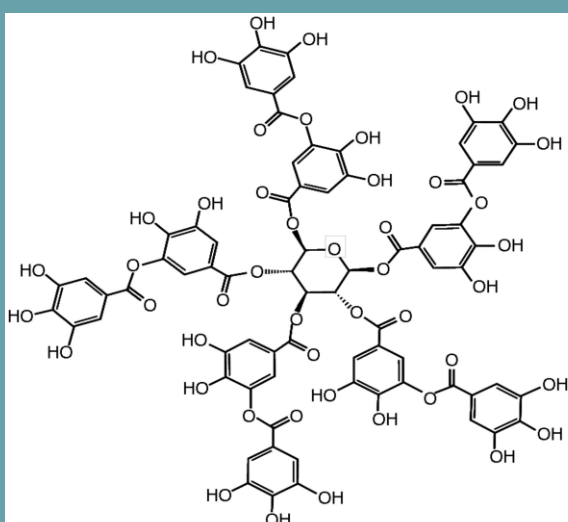
- **Flocculent material** (Floc) - the aggregation of organic particles from inside (autochthonous) and outside (allochthonous) the stream, settles together in slow moving reaches of the stream

- **Acetate** - simple, uncomplicated carbon structure, easily consumed by microbes



Dissolved Organic Carbon

DOC is a size classification of carbon that is smaller than 0.45μm in size. In order to collect and measure carbon this small, concentrated carbon solutions (leachates) were created out of our four carbon sources. These leachates were filtered through a 0.45μm filter in order to extract the DOC particles from each solution. This was the size of particles that we examined in this study.



For example, this is a **tannin structure**, a common carbon molecule in leaves.

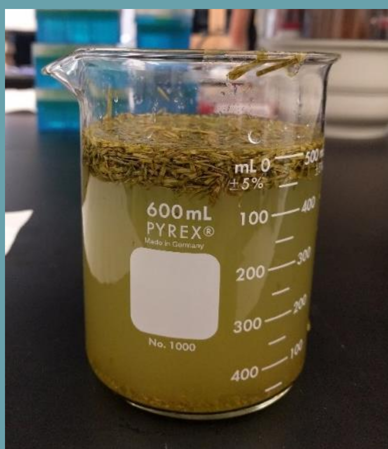
These are the **filter cartages** that were used in this study.

Research Questions

- How do different sources of carbon degrade in different stream locations (stream water or stream water + sediment)?

- How bioreactive is floc?
  - *And is reactivity impacted by medium or nutrient priming?*

Terms to Know – A Review



DOC

Floc

Nutrient Priming

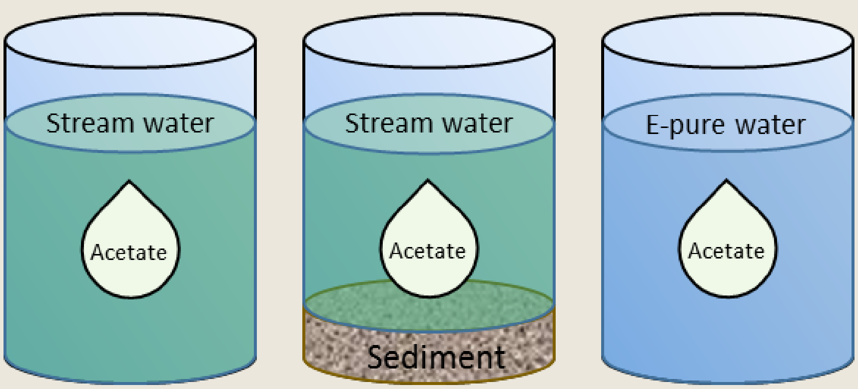
DOC - Dissolved organic carbon material less than 0.45µm in size

Floc - flocculent organic matter, formed from the aggregation of organic particles in slow moving reaches of the stream

Nutrient priming - the facilitated decomposition of carbon structures with the addition of nutrients (N, P) to the environment

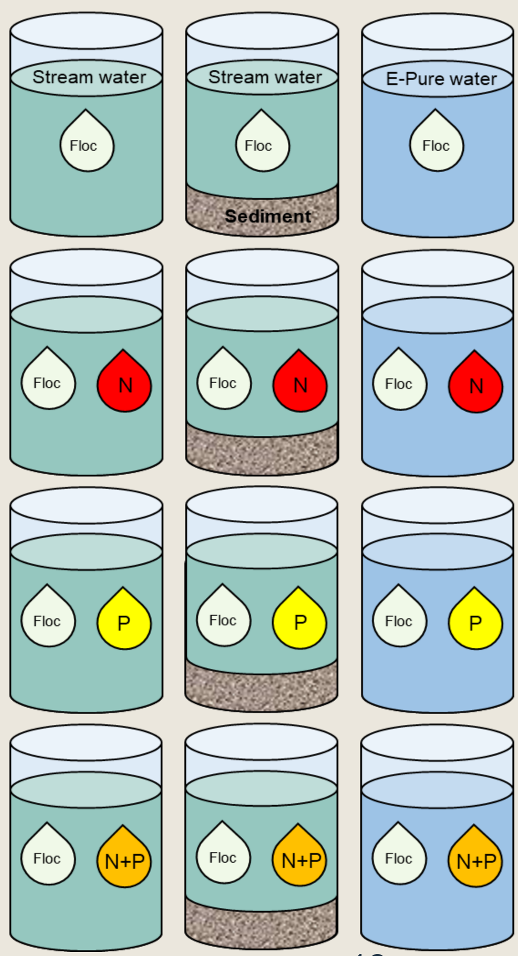
Methods – Batch Reactor

To test to degradation and bioreactivity of our different sources of carbon, we used a batch reactor model. A series of glass jars are used to simulate stream environments, while controlling for the variability in the stream. These jars also allow us to select for specific decomposition locations and control for nutrient additions to the system. Our concentrated carbon leachates were individually injected into each reactor jar and water samples were taken from the jars over time to measure the DOC concentration.



- Controls variability of stream
- Selects for specific decomposition locations
- Water samples tested for carbon across time

Nutrient Priming



Carbon Quality Comparison

Study 1

Three hypotheses guided our study on carbon quality comparison.

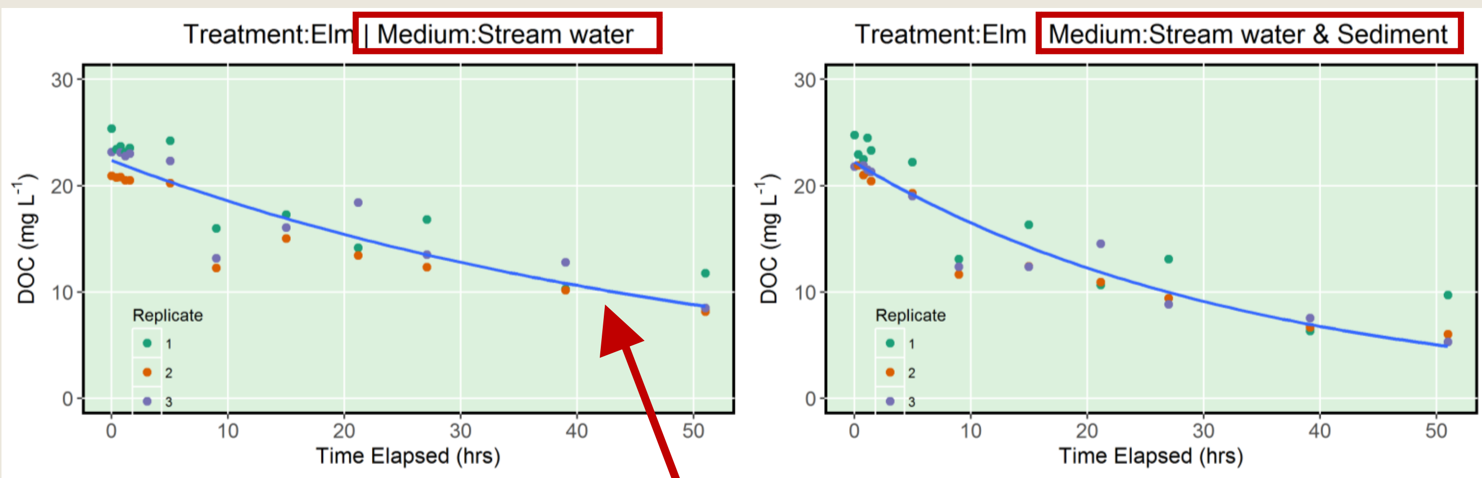
H1: Acetate would decompose most rapidly due to its simple structure and known lability

H2: Floc would degrade slowly due to its prior association and leaching time in the stream water

H3: The stream water and sediment medium would facilitate more rapid decomposition than just the stream water

How to Interpret the Figures

Carbon Quality Comparison

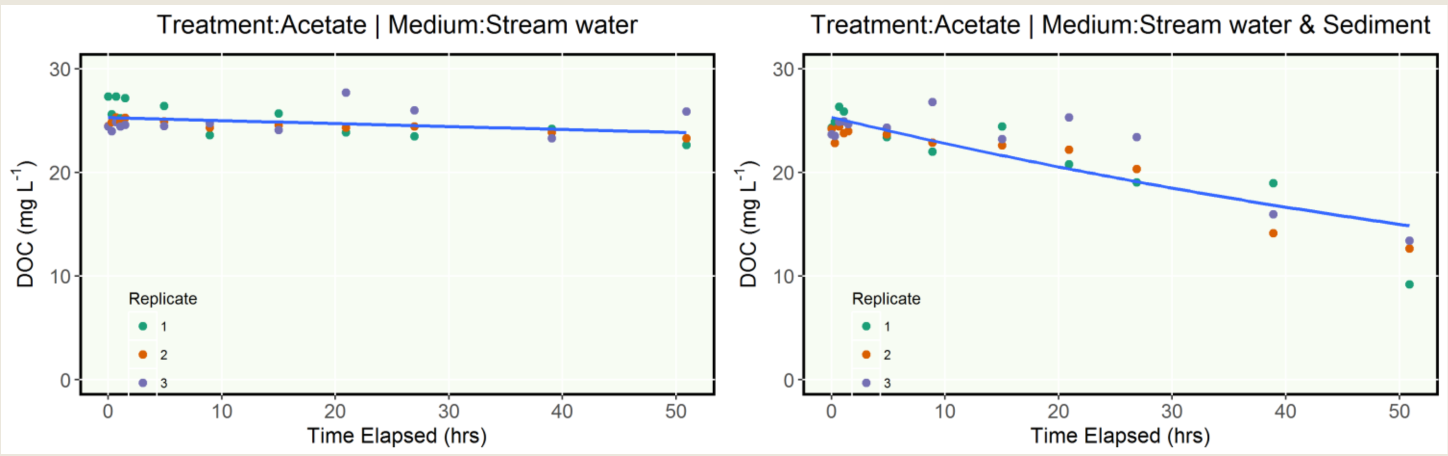


$$C_i = C_0 e^{-kt}$$

- The medium treatments of stream water and the combination of stream water and sediment are compared side by side.
- The DOC concentrations are plotted as dots over time.
- A degradation curve was fit to the points.
  - “k” represents the decay coefficient (how quickly the carbon degrades)

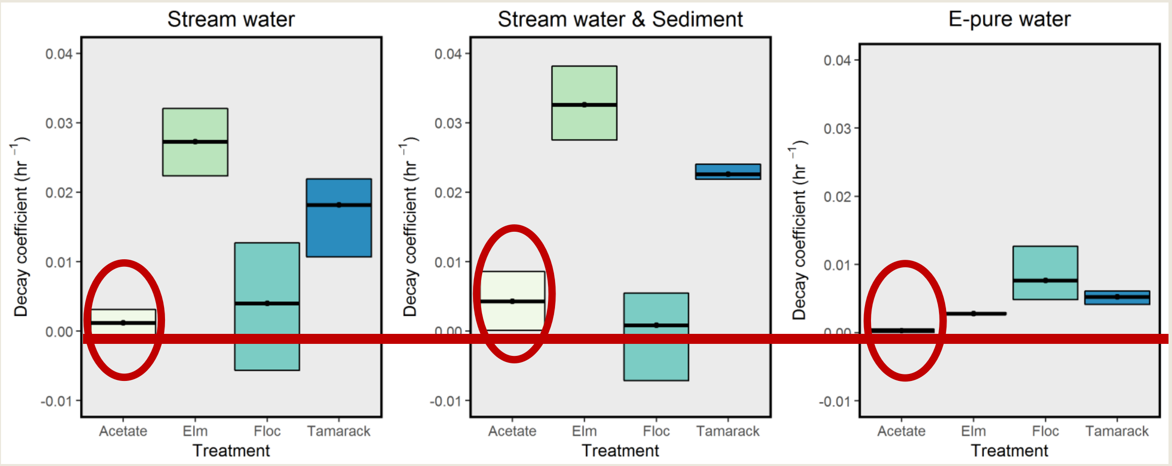
Acetate did not degrade rapidly

This is not what we anticipated because previous studies have indicated that acetate typically degrades very rapidly in aquatic environments. While the stream water and sediment combination resulted in the expected degradation, the lack of sediment resulted in little change in carbon concentration, meaning that little carbon was processed by the microbes.



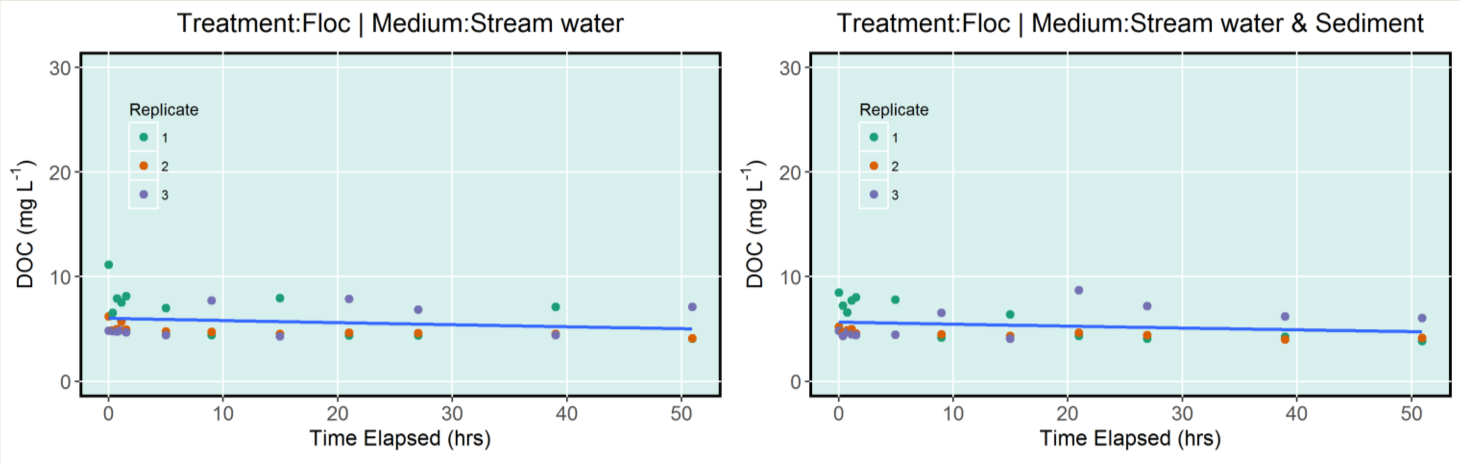
Possible Explanation:

Nutrient limitation or a lack of nutrient priming



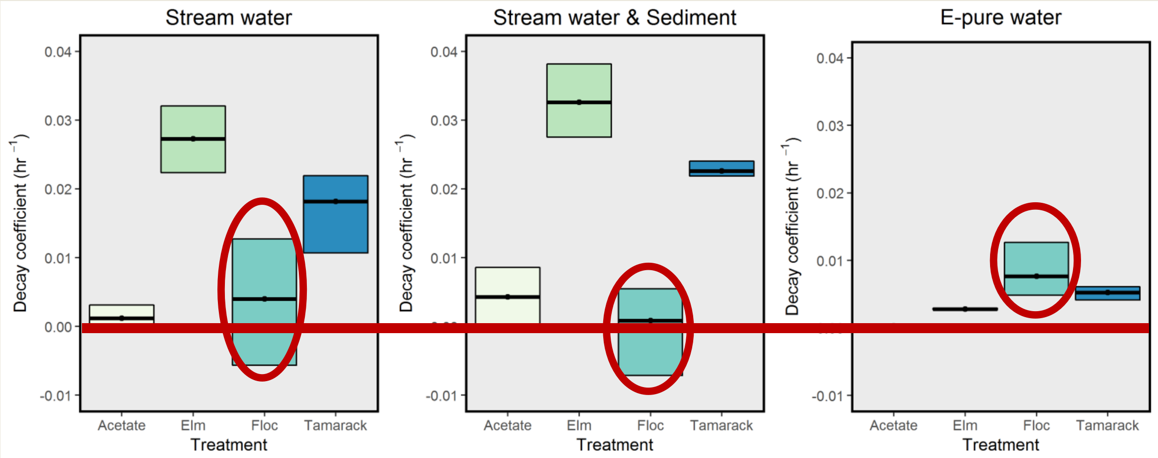
Floc showed little change in DOC

The DOC concentrations in floc show very little change from the beginning to the end of our study and the decay coefficients reside around zero. There was large fluctuation in the decay rate coefficients, which may have been due to the low initial carbon concentrations in the floc paired with our inability to elevate the floc DOC concentrations significantly above background stream water carbon concentrations.



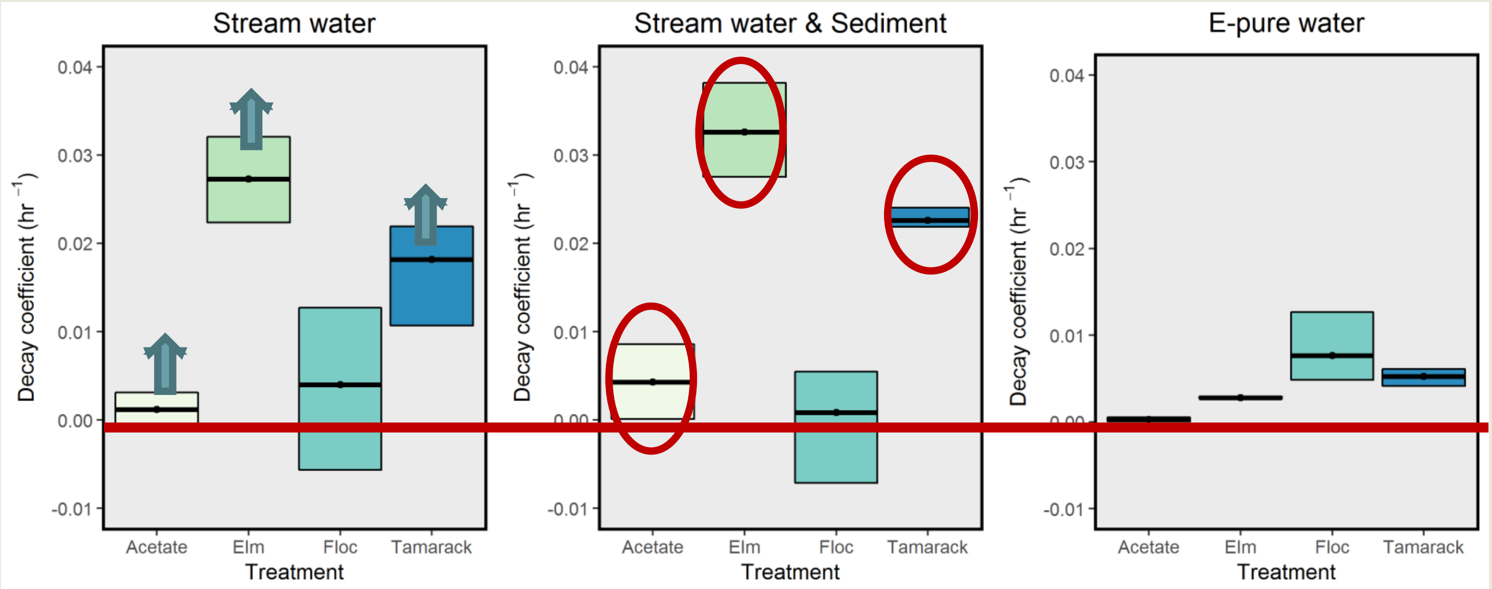
Possible Explanation:

Previous leaching in its natural setting



Increase in overall decomposition of leachates in stream water and sediment

The decay rates of acetate, elm, and tamarack increased from the stream water medium to the stream water and sediment combination medium.



Possible Explanation:
Sediment provided more surface area for microbes and may have contributed inorganic nutrients

CARBON QUALITY COMPARISON
SO WHAT?

Sediment is an important location for DOC decomposition regardless of carbon source.

Focus on FLOC

Study 2

For our second study, we focused on the bioreactivity of floc because not much is known about its role in the ecosystem.

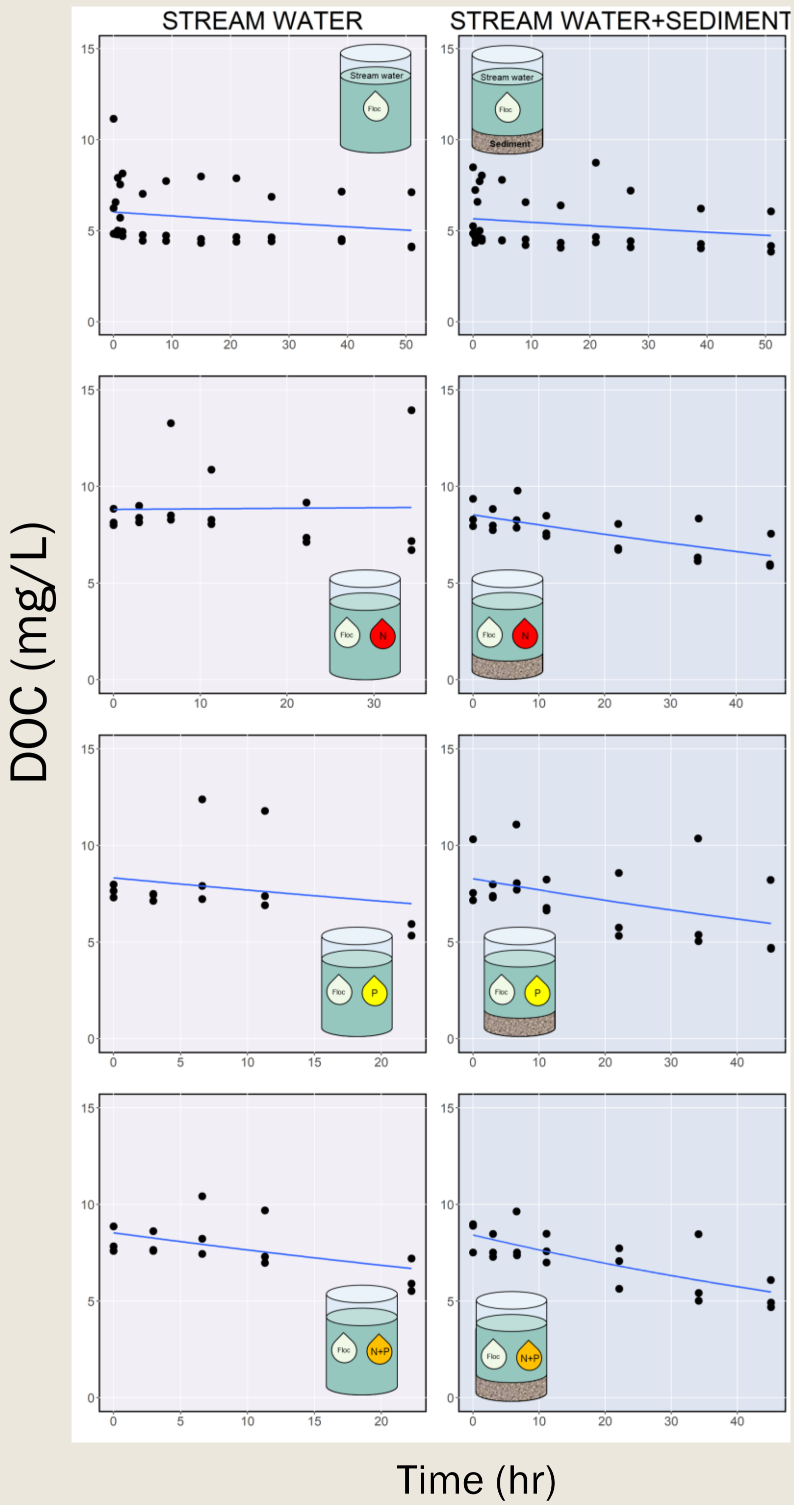
Three hypotheses guided our study.

H1: Floc has low bioreactivity

H2: Nutrient priming will not impact the degradation of floc

H3: Floc accumulates in shallow aquatic environments because of the low ecosystem demand

There was little degradation of floc regardless of medium

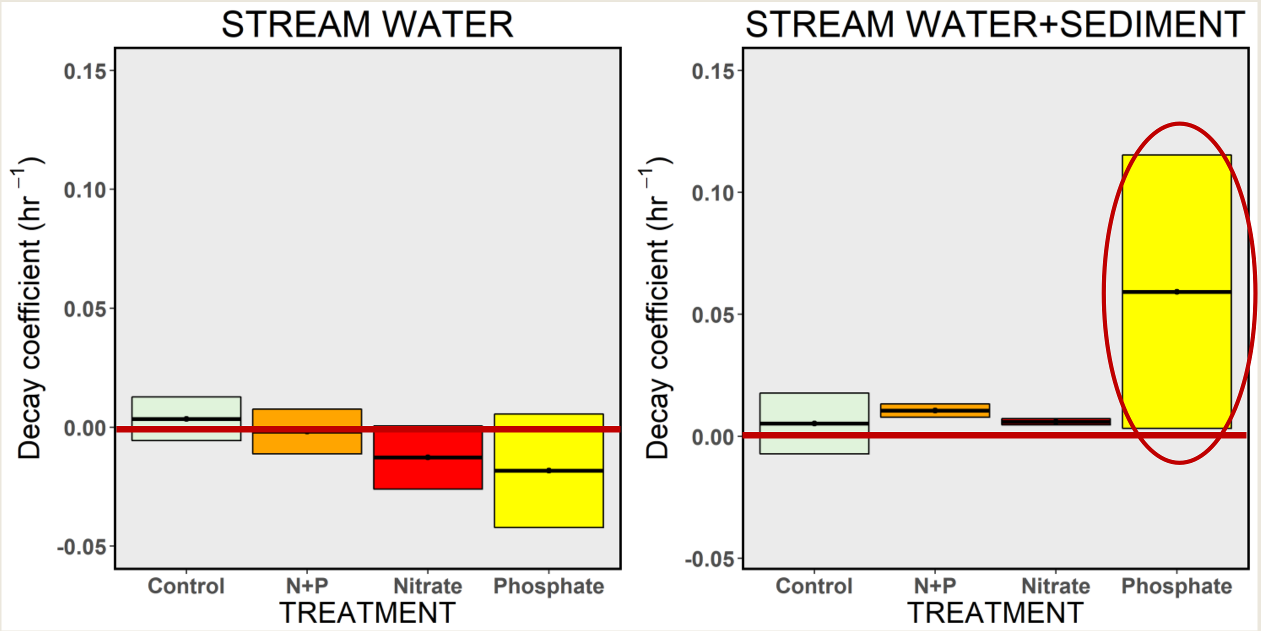


We established this concept in the previous study. Looking at the degradation curves, there is little change in DOC concentration over time, regardless of medium.

Possible Explanation:
Low bioreactivity at multiple carbon processing sites

Nutrient additions had little effect on the degradation of floc DOC

The decay coefficients are clustered around zero, regardless of nutrient addition. The only outlier may be the phosphate nutrient treatment to the stream water and sediment combination medium. This increase in measured DOC degradation could be explained by the mineralization of carbon onto the sediment particles facilitated by phosphate, rather than the degradation of carbon by microbes in the systems.

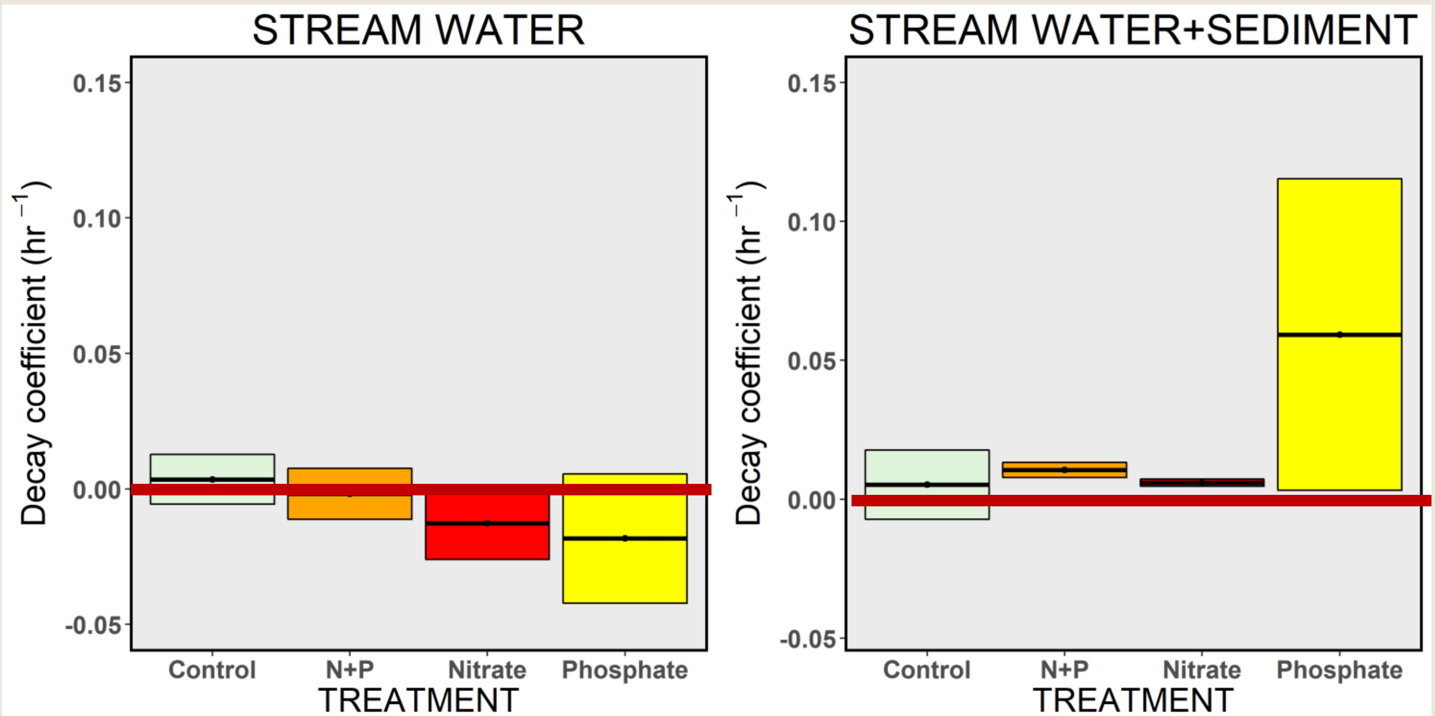


$$C_i = C_0 e^{-kt}$$

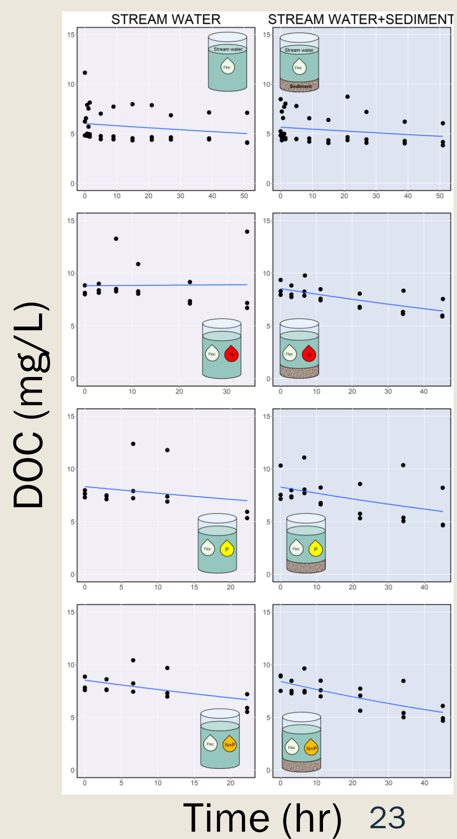
Possible Explanation:

Nutrient priming is not important in the bioreactivity of floc

Quantity of floc DOC remained stable



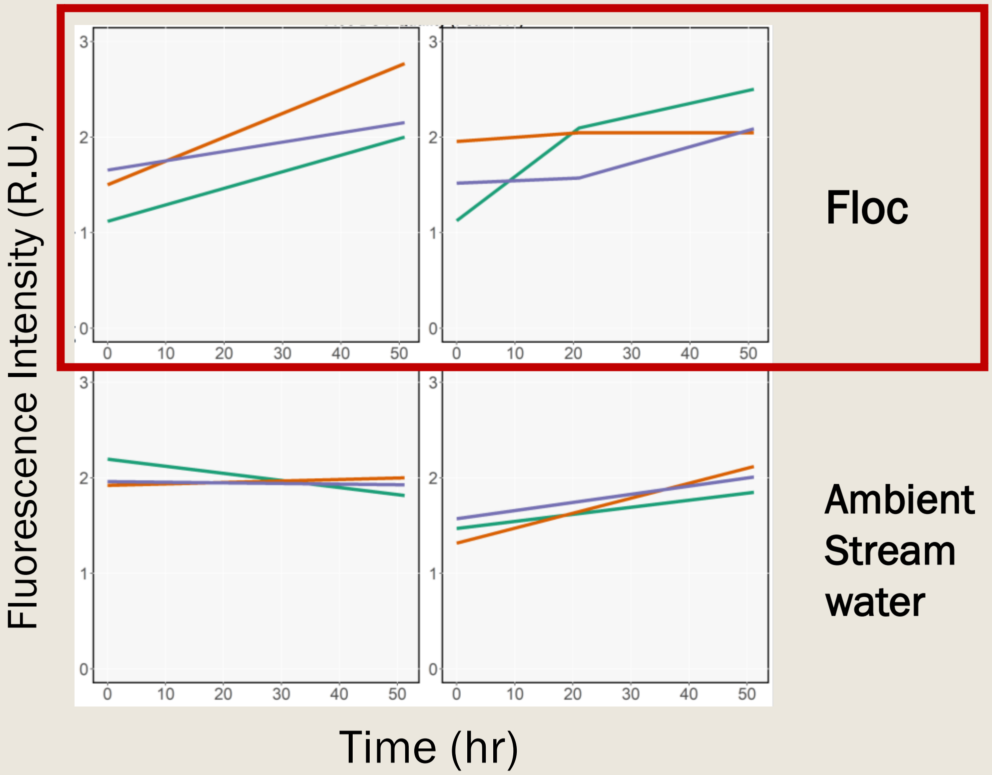
Possible Explanation:
Recalcitrant quality allows it to accumulate because of low ecosystem demand



BUT, the **QUALITY** of floc DOC does change over time to become more recalcitrant

The importance of the EEMs (Excitory Emissions Matrix) lies in the slopes of the peak lines. As the slope increase, the carbon changes shape and quality to become more recalcitrant. The molecular structure of the floc DOC changes to become more stable and less reactive within the ecosystem as compared to the carbon in ambient stream water.

Floc DOC Quality (Peak C:T) EEMs



Floc is a potential carbon SINK in aquatic ecosystems

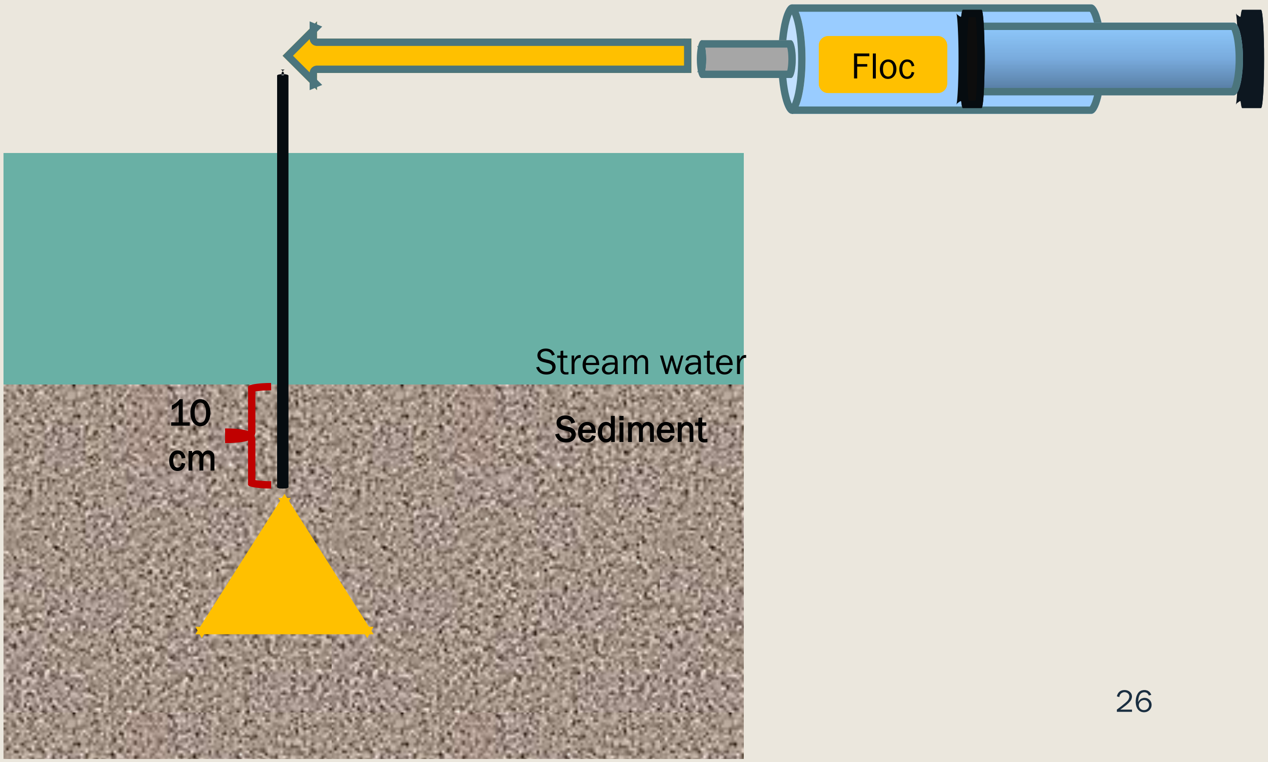
FOCUS ON FLOC
SO WHAT?

Floc DOC persists in aquatic ecosystems because of its **low bioreactivity and ecosystem demand.**

Floc is a potential **carbon sink** in aquatic ecosystems.

Future Work

These batch reactor lab studies work well to study specific processes in streams, but the complex dynamics of the stream environment may challenge our understanding of some of these decomposition processes. The next step of this experiment is to test the degradation of these carbon sources in the field by injecting the leachate solutions into the stream subsurface and comparing the degradation of DOC over time to an inorganic ion tracer. This is referred to as "push-pull" methods.



Why does freshwater research matter?

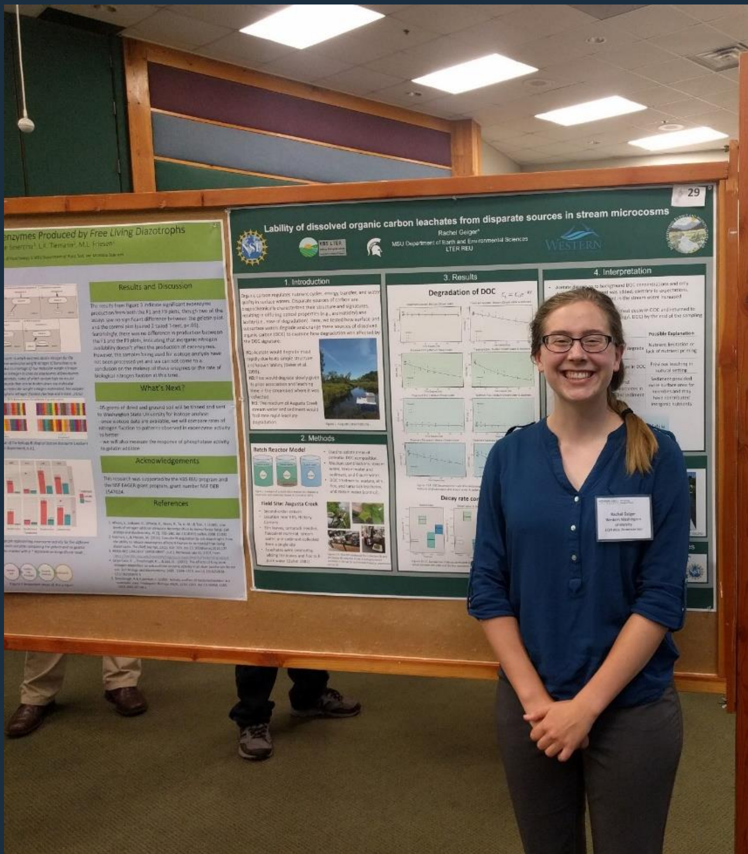
- Although only 3% of our global water is freshwater, we rely on the accessible sources fro **agriculture**, **sanitation**, and **LIFE**.

- Developing science surrounding these ecosystems can help to inform **policy makers**, **farmers**, and **recreationalists** that rely on these systems.

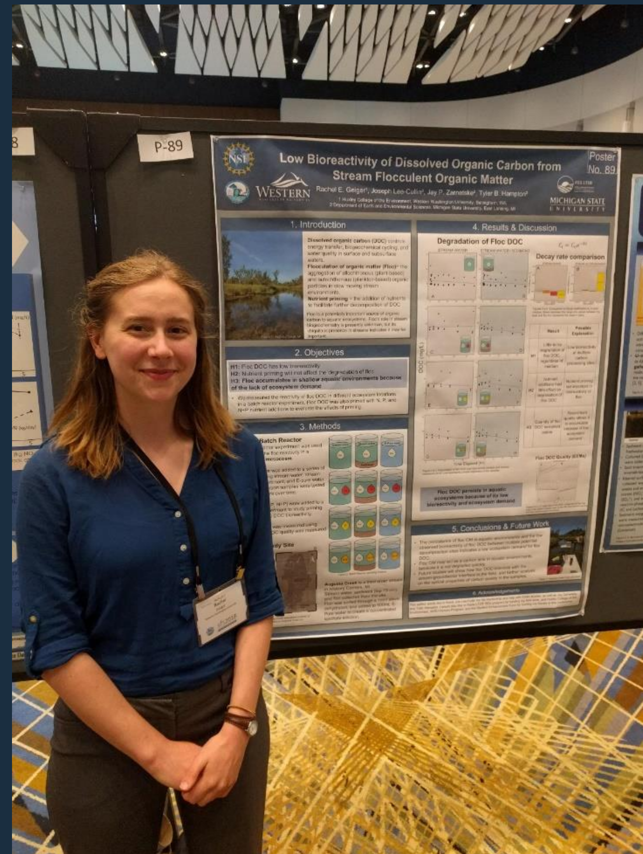
- Finding potential **carbon sinks** in the ecosystem can help us refine our carbon flux equations that go into making a **more accurate climate change model**.

WHY DOES UNDERGRADUATE RESEARCH MATTER?

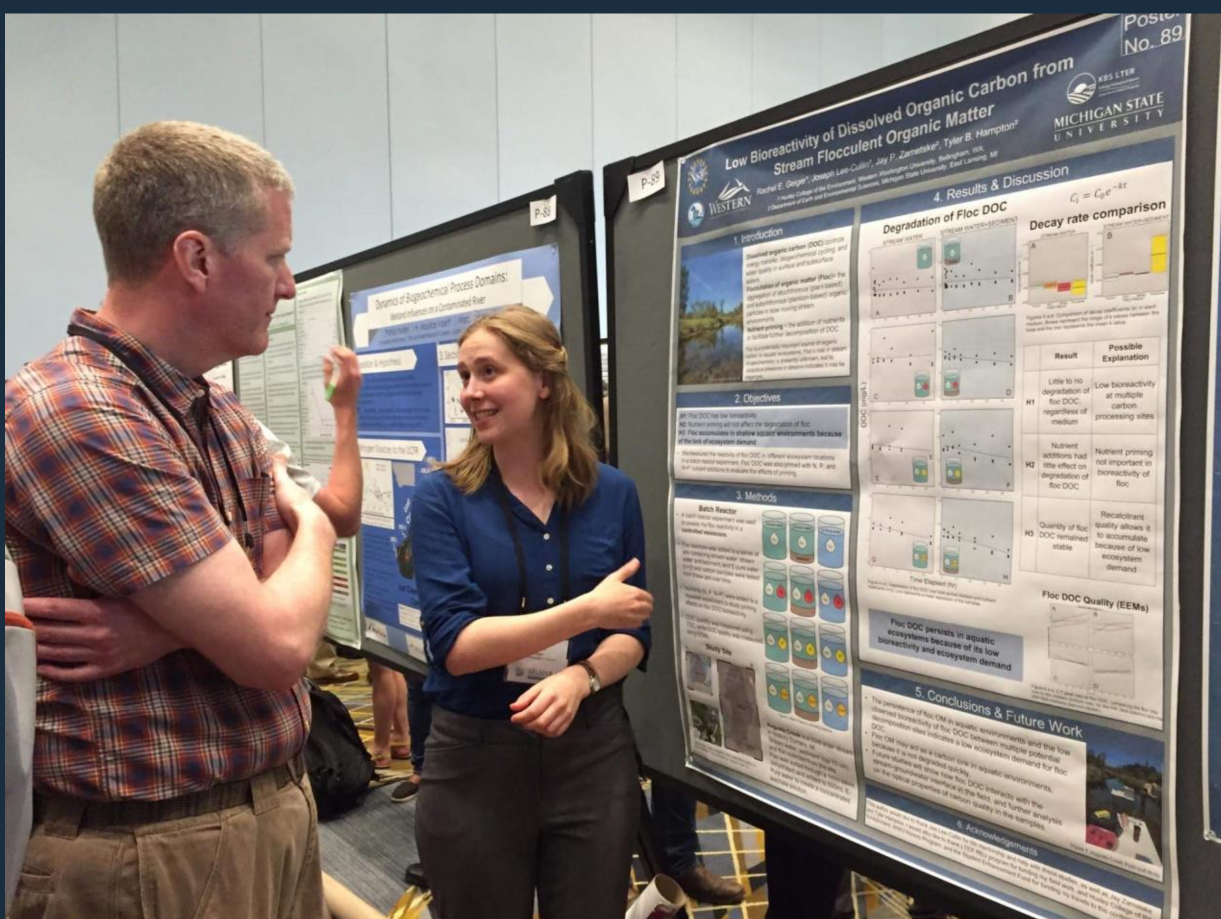
Through this project, I have had the opportunity to work closely with graduate students in a small lab, performing high-caliber research in the field. I have presented my research at a local, regional, and national scale. Engaging in scientific research as an undergraduate allows me to actively participate in the science community, engage in comprehensive scientific methods, and communicate the need for science research to a broader population. Undergraduate research has given me a taste of what graduate research could be. Through this process, I feel more prepared in my scientific career outside of academia and that I have found my calling within the field of freshwater science.



KBS Undergrad Symposium August 2017



Society of Freshwater Science May 2018



Society of Freshwater Science May 2018

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