The River Food Web

Alignment to NC Essential Standards
Science 4.L.1, 4.L.2, 5.L.2

Learning Objectives
- Students will explain the role of bacteria as primary consumers in the food web.
- Students will describe how energy moves through an ecosystem and how ecosystems recycle carbon.
- Students will describe how scientists study ecosystems.

Time Required:
Activity 1: 30 minutes
Activity 2: 30 minutes
Activity 3: 15 minutes to set up, 30 minutes for the activity.

Materials
- 1 copy per student of *Connect the River Food Web Worksheet*
- 1 copy for the class of *Reading: Scientists Studying the Tar-Pamlico River*
- Cardstock cut to 2x2" with red, green and brown colors marked on them as indicated in the activity instructions
- Tape or nametag for each student to indicate whether they are zooplankton, bacteria or dissolved organic matter
- Measuring tape

Vocabulary
Food web, producer, consumer, decomposer, bacteria, carbon cycle, stormwater runoff, dissolved organic matter, heterotrophic, enzyme, microbial loop

Overview

This lesson introduces new and exciting research conducted on the Tar-Pamlico River while addressing essential terminology for understanding the interdependence of plants and animals with their ecosystems including food chain, food web, energy pyramid, adaptation, decomposers, producers and consumers. A fun outdoor activity demonstrates to the students concepts such as how energy moves through an ecosystem and how ecosystems recycle carbon and other nutrients. The students will learn firsthand what it is like to be a scientist, as this lesson introduces two young scientists who conducted research on the Tar-Pamlico River.

Background

When talking about the aquatic food chain, we usually start with primary **producers** in an **ecosystem**, or phytoplankton. These are eaten by the small **consumers**, zooplankton, which is eaten by macroinvertebrates, which are eaten by small fish, and so on. **Decomposers** break down the organic carbon and nutrients to be used again by the primary producers. But who are these decomposers, and what are they really doing? We typically envision small organisms eating dead flesh and leaves, but what about liquid substances? Scientists call the liquid that comes from living or once living things **dissolved organic matter**.

Organic matter comes from anything that used to be alive. Dissolved organic matter (DOM) is small that it cannot be consumed by most organisms. Examples of DOM include blood, cellular fluid and leachate from leaves. (One quick hands-on example of dissolved organic matter is to put tea in a cup of water and watch the water get darker. What is causing this color change? The organic matter that is leaching from the tea leaves.) All of that organic material, which is primarily carbon, would be "lost" if it weren't for microorganisms, such as bacteria, that can eat these small, dissolved forms of organic material. Note: Scientists often interchange the terms dissolved organic matter and dissolved organic carbon primarily because while studying the dissolved matter, they are measuring organic carbon. You can choose to use either term.

Bacteria are naturally abundant in aquatic ecosystems. In addition, they can wash into rivers or streams during rainfalls, dramatically increasing their abundance. A typical amount that one might find would be a million bacteria in one milliliter of water. In polluted water, there can be hundreds of millions of bacteria in each milliliter. A teaspoon contains 5 milliliters. Often, when we learn about bacteria, we learn about harmful bacteria; those that make us sick. Most bacteria are not harmful and are, in fact, key to ecosystem functions. In this case we will be talking about **heterotrophic** bacteria, meaning bacteria that need outside sources of carbon and nutrients to eat. They are vital in the decomposition of organic matter and the cycling of nutrients.

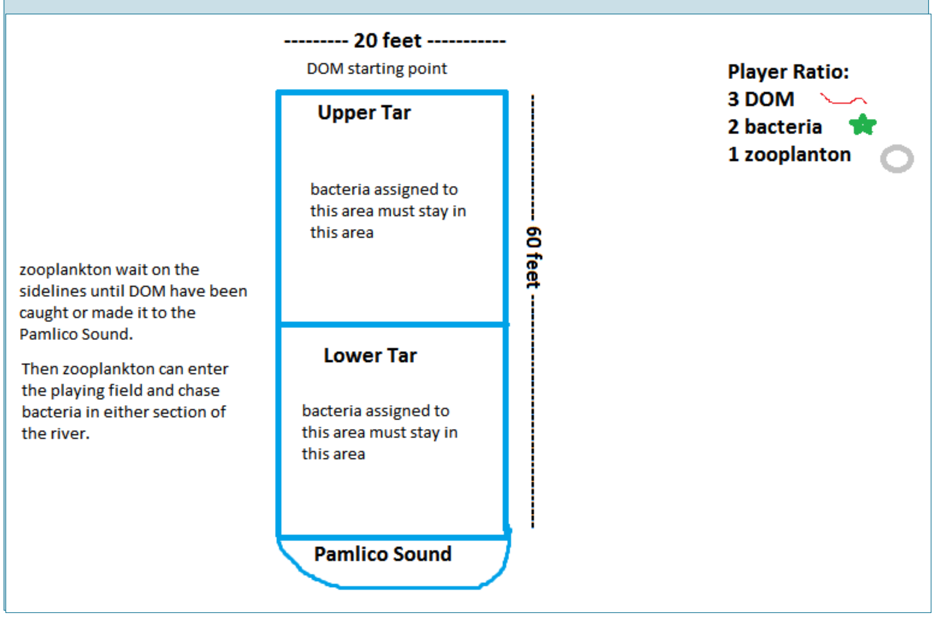
In order to break down DOM, bacteria need the right kinds of enzymes in their cells. **Enzymes** are molecules required for metabolic processes. If bacteria are eating DOM that is common to their stream, they will most likely have the enzymes needed to break down that carbon. If the material were swept into the stream from **stormwater runoff**, the bacteria may not be adapted to consuming that type of carbon and wouldn't have the proper enzyme(s). What happens to that material? If there is a lot of it, brought by a large storm, the few bacteria that can consume it may thrive, and the population will grow to consume the organic matter. If there are no species of bacteria that can consume the organic matter, it will either be buried in the sediment at the bottom of the river or carried downstream all the way to the estuary and then the ocean. There, it may be buried in the ocean sediment for thousands or even millions of years.

When bacteria eat this dissolved form of carbon, they thrive and become food for zooplankton. They also release carbon dioxide and other nutrients, which can be utilized by the phytoplankton. This aspect of the food chain is not shown in most food chain diagrams because it was not discovered until the 1970s. It was first studied in the ocean by marine biologists, and research on rivers began in the mid-1980s. Only in the past 15 years has the technology advanced to a level where ecologists can identify where the DOM originated (land vs. aquatic, animal vs. plant) and identify which species of bacteria are eating different types of DOM. This part of the food chain that focuses on how DOM is processed by bacteria is called the **Microbial Loop.**

Preparation

To prepare the activity playing field, mark off the parameters of the river. The river should be about 60 feet long and 20 feet wide. Divide the 60 feet into two 30 foot sections. At the bottom of the river is the sound (safety for the DOM). The area may need to be enlarged if you are playing with bigger kids.

Setting Up the Microbial Loop Activity



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Procedure

ACTIVITY 1
Drawing the River Food Web
Time: 30 minutes

1. Pass out copies of the river food web worksheet.
   - Review the concepts of food web, primary producer, consumers and decomposers.
   - Ask students to label the images as primary producers, consumers or decomposers.
   - Ask students where all energy comes from. (*The sun*)
   - Tell them to draw arrows to where the energy goes next or, in other words, what uses sun directly to make its energy. (*Plants, algae, phytoplankton*)
2. Now ask them to start thinking about other connections on their own.
   - What might eat the plants, algae or phytoplankton?
   - How do the leaves fit in? (*Leaves are organic matter that comes into the river from a terrestrial source. A lot of organic matter comes from trees and plants that grow on land*).
   - Can bacteria eat multiple things in the diagram?
   - Tell them that they can draw multiple arrows to or from one organism.
3. Someone might ask, "What is dissolved organic matter?"
   - Talk to them about waste from the organisms that float around in the water.
   - Have them draw dashed arrows from organisms that they think produce some sort of liquid waste, to the dissolved organic matter image.
4. Finally, ask what they think happens to this waste. (*Bacteria consume this dissolved organic matter*.)
5. *Note: If you discuss carbon dioxide with your class, this is a good place to let them know that through this process of energy transfer through the food web, carbon dioxide is released into the atmosphere.*

ACTIVITY 2
Scientists Studying Bacteria and Organic Matter in the Tar-Pamlico River
Time: 30 minutes

1. Select a student to read about the scientists who study bacteria and organic matter in the Tar-Pamlico River. Then select other students to read what each scientist said about their work.
2. Ask students to think about what the prefixes micro-, bio- and geo- mean based on what they already know. Once they provide answers, either share definitions with them or have them look up the definitions.
3. Other questions to ask:
   - Why would one scientist need to know all of these areas of science?
   - Where do these scientists work?
   - Does it sound like they like their work? Why?
   - Why is it important that scientists learn about bacteria?
   - Why is it important to study the health of the river?
4. Plan to ask these questions again after the game is played in Activity 3.

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ACTIVITY 3

The Microbial Loop

Time: 15 minutes to get the students set up, 30 minutes for the activity.

1. Tell students that what they are about to learn in the next activity comes from the work that JP and Avery did in the Tar-Pamlico River.
2. Define dissolved organic matter and bacteria.
3. Tell students that they are going to act out the part of the food web that is difficult to see. They will learn that a lot of carbon/energy moves through the river ecosystem. Bacteria consume the DOM if they have the right tools to do so (the right enzymes). The best way to describe it is that each type of bacteria has tools to break apart certain kinds of DOM so they can eat it. If the DOM comes from the land, but the bacteria are familiar with DOM that comes from the river, they may not be able to eat it (just like different types of animals have different types of teeth depending on what they typically eat). The more DOM the bacteria can eat, the more they multiply, and the more energy moves up the river food web.
4. Take students out to the already set up playing area and divide the students into roles. Numbers will vary based on how many students there are but the ratio should be 3 DOM : 2 bacteria: 1 zooplankton.
5. Secretly provide some students with colored cards. For example, if you have 24 students, 4 students playing DOM will get a red card, 4 will get green cards and 4 will get brown cards. Assign 4 students to be red bacteria in the upper 30 feet of the river and 4 students to be green bacteria in the lower 30 feet of the river. Assign 4 students to be zooplankton.
6. At the start of the game, the DOM will run from the top of the river toward the sound, trying not to get caught. The red bacteria will try and tag the DOM. If a DOM is tagged, he or she must show their card to the bacteria. If the red bacteria caught someone with a red card, then they have a match, and the DOM is eaten and becomes another red bacteria. If it is not a match, the bacteria have to let the DOM go. The DOM continues to run toward the sound while the green bacteria also tries to tag them and make a color match.
7. Once the DOM are either converted to bacteria or escape to the sound, the zooplankton come into the game and the bacteria now become the food. The bacteria can run around but must stay within their upper or lower 30 feet of river. If a zooplankton tags at least 3 bacteria, it survives. Otherwise, it does not have enough food and does not survive.

NOTE: There will be some chaos in the game. This is representative of how the food web really works in an ecosystem and provides an opportunity to let the students know that even though we often teach the food web in a clear way to make it easier to understand, in the natural world, a lot more is happening all at once.

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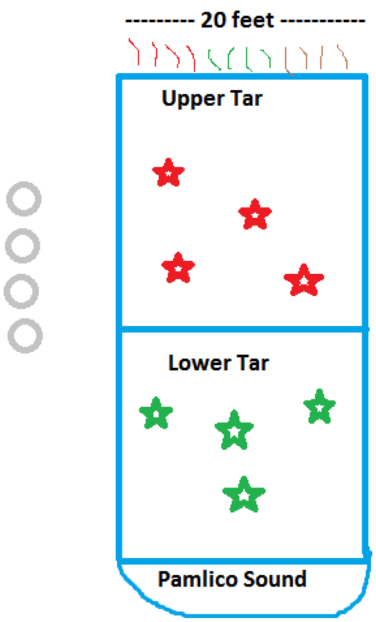
Scenario 1: Average Day at the River

8. Run through scenario 1 once so that students can learn the rules and then do it again so that they can begin to understand the concepts.



Player Ratio:
3 DOM
2 bacteria
1 zooplanton

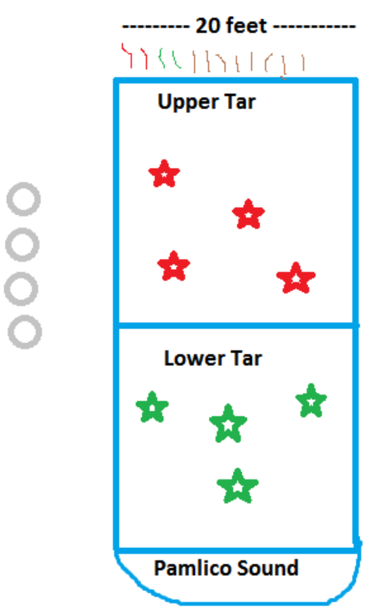
Instructions:
This grahic assumes 24 students in the class. Assign 4 students to be zooplankton, 4 to be red bacteria in the upper Tar and 4 to be green bacteria in the lower Tar. Do not tell the DOM what colors you assigned to the bacteria. Give the 12 students who represent DOM a card with a color marked on it. 4 should get red cards, 4 green cards and 4 brown cards.

The DOM will run from the start, to the Pamlico Sound. The bacteria must stay in their assigned upper or lower Tar. The bacteria must tag the DOM. If the DOM colored card matches the bacteria color, that DOM is consumed and becomes bacteria and stays in that part of the river. Once the other DOM have made it to the sound, the zooplankton enter the playing field and try to tag as many bacteria as possible.

The zooplankton that tag at least 3 bacteria, survive. The others do not.

Scenario 2: After a Large Rainstorm

9. In scenario 2, secretly give 2 DOM red cards, 2 DOM green cards and 8 DOM brown cards. The bacteria colors remain the same. In this scenario tell the students that a big rainstorm came and washed a lot of carbon material into the river from the land. Afterwards explain that in this scenario, the bacteria were not equipped to consume this carbon from the land. Don't forget to let the zooplankton eat!



Player Ratio:
3 DOM
2 bacteria
1 zooplanton

In scenario 2, secretly give 2 DOM red cards, 2 DOM green cards and 8 DOM brown cards. Play the activity with the same rules as the first scenario.

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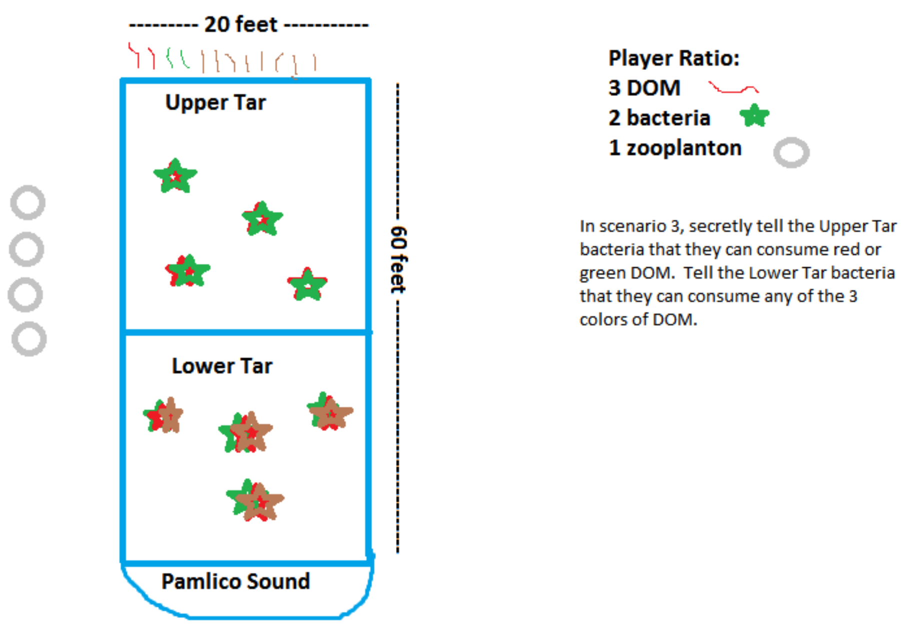
Scenario 3: Bacterial Communities Have Adapted to Consume More Organic Matter

10. In scenario 3, tell the first group of bacteria that they can now consume green or red DOM. Tell the lower river group that they can now consume any of the three colors. Alert the DOM that the bacterial communities have adapted to the new DOM sources and they may be eaten by bacteria that couldn't eat them before. The individual bacteria itself does not adapt. The types of bacteria that can eat the brown DOM have multiplied because there is now a food source.
11. If the students understand the activity well and you want to make it a bit more realistic, let the zooplankton feed on bacteria at the same time the bacteria is feeding on DOM.



12. Here are a series of discussion questions that can be done between scenarios or after all of them have been done.
    - What would happen if nothing could eat dissolved organic matter? *At some point in the day, all living organisms release dissolved organic matter into the ecosystem, whether it is blood, cellular waste, urine or respiratory byproduct. If this process continued, releasing carbon and other elements into the system, all of that energy would be lost.*
    - Why is it important that the bacteria consume the DOM? *Because they are the only ones that can consume such small matter and when they do, they multiply and become food for the rest of the food web, as represented by the zooplankton in the game.*
    - What happens to the DOM that does not get consumed by the bacteria? *DOM continues downstream where other types of bacteria may consume it. Another possibility is that it sinks to the bottom of the estuary and gets buried for a long time.*

14. Revisit the questions from Activity 2, step 3. Have the student's answers changed?

Assessment

Assessment will be based on teacher review of the food web worksheet and observation of the Microbial Loop activity, including student responses to discussion questions.

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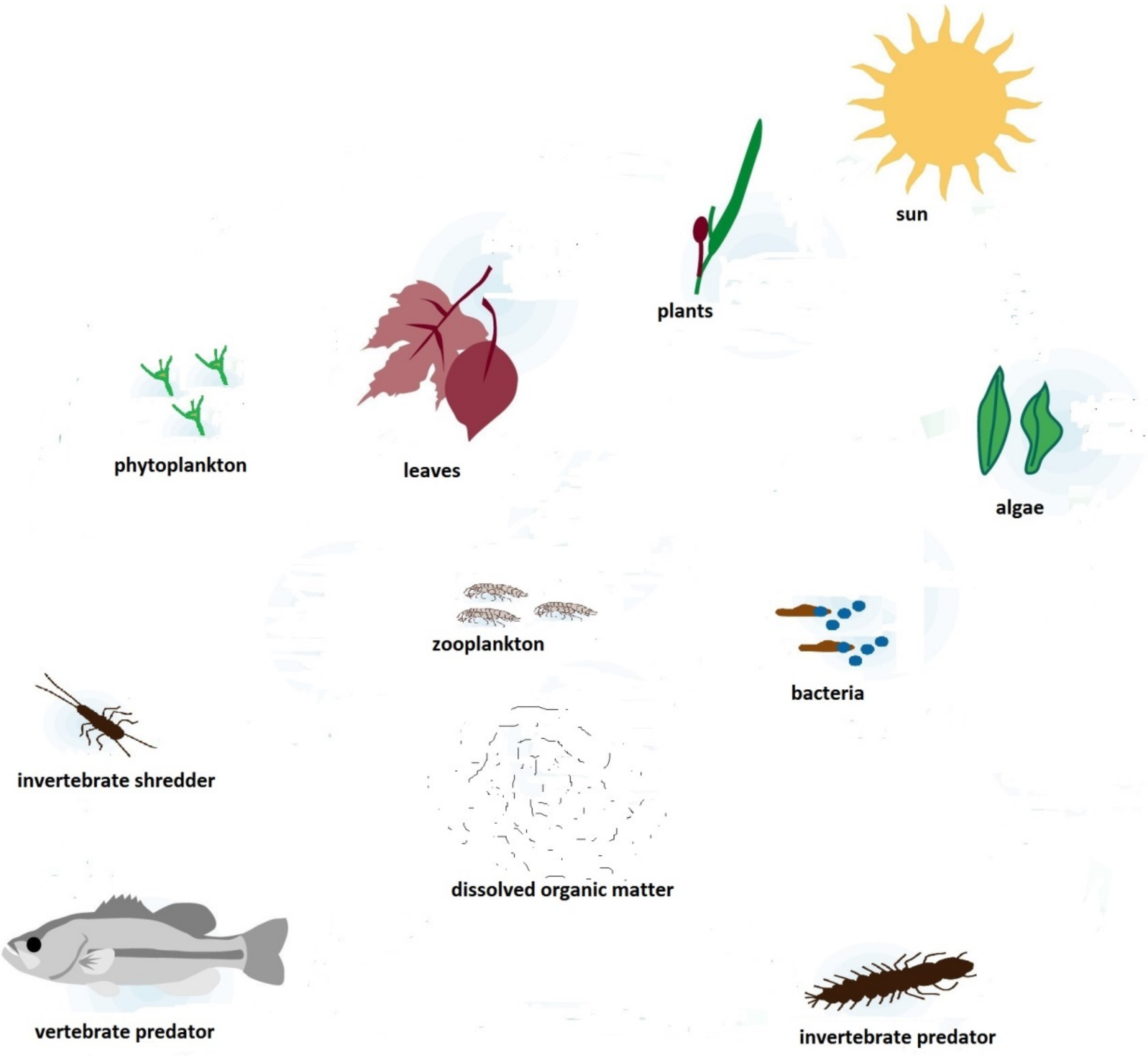
CONNECT THE RIVER FOOD WEB Worksheet

Name___________________________



READING: Scientists Studying the Tar-Pamlico River

Scientists Who Study Bacteria and Organic Matter in the Tar-Pamlico River

There are scientists working in the Tar-Pamlico River to understand what types of bacteria live there and what kind of dissolved organic matter they eat. These scientists drive to many locations along the river, from the top to the bottom, and collect containers full of water. Back at the lab, some of the scientists study the bacteria and some study the types of organic material that is floating in the water. Scientists can actually figure out if organic material comes from animal waste, leaves from trees, or plants that grow in the water. The scientists study what kind of organic material is in the water and then compare their results with the scientists who are studying what kind of bacteria are in the water. This gives them an idea of what kind of "food" bacteria are eating, which is important because we are still learning about parts of the river food web and how energy moves through the river ecosystem.

Below, two scientists from UNC-Chapel Hill, Department of Marine Sciences, write about their work.

"My name is JP and I study bacteria in different environments -- from the rivers of North Carolina to the Arctic Ocean. I call myself a microbiologist. I am very interested in what types of bacteria are present in the environment and understanding why it is that they live there. For example, when we look at the bacteria community in a river, we find that they are made up of bacteria that always live in freshwater as well as bacteria that live in the soil on land and were probably washed into the water by rain runoff. Or as another example, in the Arctic, we have bacteria that can survive very cold weather. I do this type of research because bacteria, even if they cannot be seen without a microscope, are the ones that cycle nutrients and elements in the environment. This is important for every organism because they all need different types of nutrients and elements in their habitat. Bacteria are simply amazing!"

"My name is Avery and I am a marine biogeochemist, which means that I study how cycles (like the carbon cycles) interact with ecosystems (like rivers and oceans). I've always been interested in how bacteria make things happen in the natural world and in biology and chemistry, since they are the science behind life. I think there is something really cool about understanding how life works at the most basic level. In my job, I can go out to the river to collect water samples but I prefer to work in the laboratory."