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Tributary 2: Streams, Rivers, Watersheds 101

In this section we present a broad overview of key watershed concepts and terms. Use the information here as you need. Some of the content may be new, some may be review. What strikes us as we write this chapter are the physical and biological complexities of stream and river ecosystems, and the myriad interactions within them, some hidden, others more apparent. Moreover, there are interactions that happen between the stream/river and the surrounding terrestrial landscape. Neighboring ecosystems are interlinked. What is also present to us is the significance of scale on stream and river ecosystems. Watershed scale features such as hills and mountains and underlying bedrock, and large scale land use practices, influence how water flows through the landscape. Within streams and rivers themselves, smaller scale features such as downed trees, and piles of rocks or stones influence water velocity, depth and water temperature, and the quality and quantity of habitats. This chapter is designed to provide learners with background knowledge of these incredibly dynamic systems in preparation for stream/river assessments and research.

Making Observations

Science is rooted in making observations and asking questions. Thoughtful humans from a variety of disciplines have made groundbreaking discoveries and produced spectacular works of art because of their highly refined abilities to notice something that does not fit the usual pattern, or their curiosity coupled with skilled observation revealed something that was previously hidden from view. “Something-slightly-different” or “previously-hidden-from-view” may spark questions that throw open the door to a whole new way of thinking and understanding. Groundbreaking discoveries, spectacular art, and new ways of thinking are not the only reasons however, to hone observation skills. There are other, more elemental reasons. Noticing can lead to wondering, wonder, and feelings of connection and joy.

Here are some ideas to prepare students to strengthen their abilities to observe. An observation is something perceived through the senses. Observations are what you notice, not what you already know. Observations describe an object. Saying "it is brown" is an observation. Students, however, may have the habits of substituting opinions or names for actual observations. Saying "it looks awesome" is an opinion, not an observation. Saying, "it is a shell" is an identification not an observation. Be alert for this happening, so you can elicit true observations from your students.

Ideally, take students out onto the school yard. Let them pick one object, a leaf, a rock, a twig, etc. If you are not able to take your students outside bring a larger natural object into the class, something big enough for all of the students to see as they sit in a semicircle/circle around the object. Or bring a collection of enough natural objects such as shells, seeds, or stones so that each student has one. Students should shake, listen to, smell, touch, look at in its entirety, their object to really "see" it with all of their senses except for taste. Recently, I was on a walk with a skilled naturalist in dryland habitat, and he taught us to listen to the sounds the plants make when we walked over them. He was able to identify some by the sound of their "crunch."

Next, students should say their observations out loud starting with the statement " I notice…" Acknowledge that talking to themselves may feel uncomfortable at first, but it will help them develop good observation skills. They can also share with a partner. If students get stuck help them make a basic observation like color. Suggest they listen to people next to them to get ideas for describing their own observations.

Here is an additional idea to consider when making observations: how much exists beyond the surface of whatever subject we are observing that we cannot see.

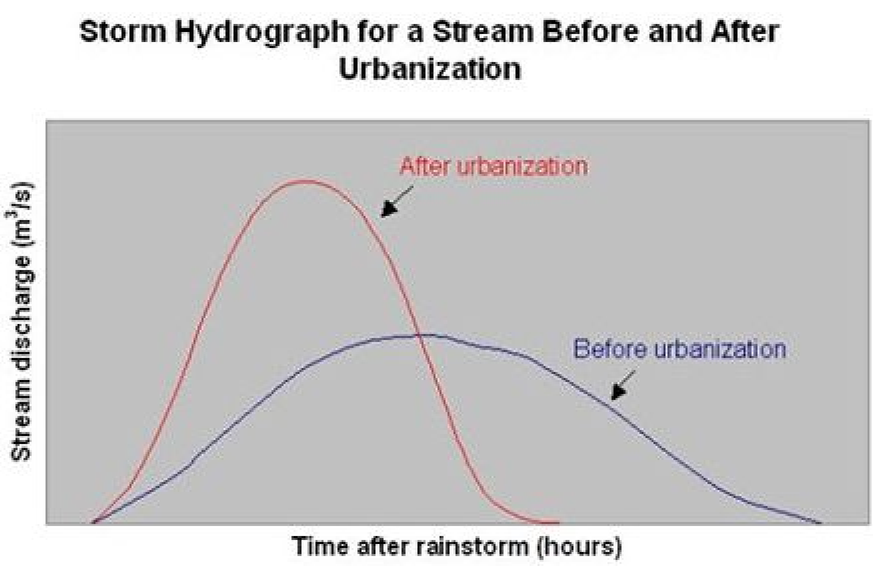
Watershed

Figure 3. Photo of the confluence of two streams, MD, USA

What do you notice in this photo of where two streams meet? Do you notice how the two streams are different colors, and how they have different levels of turbidity? The stream on the left is very murky, with zero visibility, but the stream on the right is more clear. What do you wonder? Do you wonder why this happens?

It comes down to watershed. The river on the left has a watershed that is dominated by agriculture and residential development. The stream on the right has a watershed that is mostly forested. *Watershed land use is the single most important factor that determines water quality.*

A watershed is the area of land that drains into a water body. Watersheds can be extensive in area. The Chesapeake Bay drains 64,000 square miles of land from six states: New York, Pennsylvania, Delaware, Maryland, Virginia, West Virginia. What we do on land directly affects the water quality of the closest water body in a watershed. In fact, the cleanliness of the water in a watershed depends on how well the land in it is managed. Forested watersheds produce the cleanest water. When it rains, the rainwater in a forest percolates through the soft forest leaf duff and soil and does not directly run off to the local stream. As rainwater percolates through the soft forest soil, it is filtered. When rain falls on an agricultural watershed, more water runs off directly to local streams and carries soil, fertilizers and agricultural chemicals with it. When rain falls on a suburban or urban watershed, any water that lands on impervious surface - a hard surface that doesn't allow the rain to soak in - runs off and carries contaminants that are on the surface with it. Oil, antifreeze, brake dust (which is high in heavy metals) coming from vehicles, and fertilizers are all carried in the water, which runs rapidly to the local creek. Since the water coming from impervious surfaces runs with high velocity, it scours soil and turns the water muddy.



Assignment 2a. Analysis of a Hydrograph

What do you notice about this hydrograph? (Goldman, 2008.) Make a statement supported by CER based on the data represented in this hydrograph.

Claim-Evidence-Response (CER)

CER is a simple and effective three-part method of conclusion that requires students to use multiple ways of thinking. CER stands for Claim, Evidence, Reasoning (NSTA, 2015). Formulating a CER report requires students to state empirical scientific information and draw reasonable conclusions, while leaving space for focused creative thinking.

The claim is a matter-of-fact answer to the original research question. Evidence is specific data and hard facts that support the claim. Reasoning is educated speculation that outlines the relationships between claim and evidence. The claim and evidence will be empirical and will not vary within a group of students working on the same study; the reasoning calls the student to apply critical—and creative—thinking and will be unique to each student.

For example, let us consider the vulture lesson taught at NorthBay Adventure Camp on the upper Chesapeake Bay. Students have access to a bank of historical data; they also gather current data within the guidelines of a research question. The standard research question is, “To what extent is the vulture population changing over time at NorthBay?” Students collect data on the current vulture population, based on a 20-minute observation time. At the end of the lesson, they are instructed to formulate their own CER reports.

Here is an example of the CER that would be produced by this study. Claim: The vulture population is changing over time. The population of turkey vultures is increasing over time, while the black vulture population is decreasing. Evidence: Today in our data collection, we observed 11 turkey vultures and 3 black vultures. In the past 4 years, there have been equal numbers of turkey vultures and black vultures observed.

Reasoning: Black vultures can see very well, but cannot smell. This makes it difficult to locate carrion in wooded habitats. They have most likely started living in other habitats that are less wooded. – OR – Today was a cold rainy day. It is possible that black vultures are more likely to take shelter on such days. The population may be constant, but they were not present today.

Sediment Pollution: When soil is washed into water it is called sediment. Cloudy water is called turbid and turbidity is a measure of how cloudy the water is. The root word for the units of turbidity, Nephelommetric Turbidity Unit (NTU) is “Nephelos” which is Greek for “cloud or cloudy”. Sediment has different impacts. One is that sediments can smother bottom habitat in aquatic environments. Streams thrive when they have diverse habitat with lots of nooks and crannies that provide habitat for an array of species. Many fish lay their eggs on clean gravel bars and cobble, and many benthic macroinvertebrates cling to these rocks and take advantage of the oxygen and food that rushes by. When sediment settles out, it buries these rocks and the bottom becomes a sand or mud flat with little habitat diversity. Low habitat diversity means little biodiversity. Fish that rely on cobble for reproduction leave, and benthic macroinvertebrates can’t make their homes in the sand and mud. The quality of the stream declines.

Some fish species use eyesight to feed. When they can’t see due to cloudy, turbid water, they can’t eat, and they must try to move to places that have cleaner water. Other types of animals also depend on clean water to survive. Hellbender salamanders are the largest salamander in North America and are declining in number partly because of increased sedimentation. T*he Last Dragons,* https://vimeo.com/108512185 is an amazing 10-minute film by Freshwaters Illustrated that shows the plight of the Hellbender and how the U.S. Forest Service is working to protect them.

Nutrient Pollution: Nitrogen and phosphorus wash into our rivers from agricultural and suburbanized land. These nutrients come from animal waste, human sewage, pet waste, lawn fertilizers, and car exhaust. Septic tanks do nothing to reduce the nutrient levels of human sewage, and sewage treatment plants often don't reduce nutrient loads. Excess nutrients in water sources can make excess algae grow.

Algae are an important food source for streams and 50% of the food needed for a river's food web comes from algae. Too much algae from too many nutrients results in eutrophication. Phytoplankton, or single celled algae, live for a short duration then die. When they die, bacteria decompose the dead algae and use up available oxygen in the decomposition process, which results in oxygen levels too low to support life, especially in deeper, slower moving, sections of the stream. This process is called eutrophication.

Other Pollutants: Contaminants that wash into rivers and streams from suburbanized and urbanized landscapes include heavy metals and petroleum products. These can be directly toxic to stream life and to us. It can be a stretch to think that turning off unneeded lights could impact stream health, but this action does have an effect, and here is how. Coal is still a major source of energy. We burn coal in power plants to boil water to produce steam which powers turbines that generates electricity. A byproduct of this product is mercury, a heavy metal. It is released into the atmosphere and brought down to earth and washed into streams by rain.

Although humans are responsible for many pollutants entering the water they can also be a part of the solution. We encourage you and your students to generate solutions by conducting research that leads to action on behalf of local waterways. Planting trees in agricultural, suburban, and urban watersheds can help restore water quality, and installing rain gardens, green roofs and other engineered green infrastructure used to control runoff can make a big difference to the life of a stream. Each of these practices controls runoff and absorbs or transforms contaminants, all of which restore water quality. A copy of NorthBay's stormwater lesson for middle thru high school students can be found in the "Gifts for Teachers" section of this course should you wish to try it out.

What we do on land affects water quality, and water quality affects those downstream. In a very real sense, all rivers eventually flow together. We are all connected through water and we are all downstream and upstream of someone else. What we do on land can affect someone on the other side of the world. We are all connected in one large global watershed, and our actions impact everyone else.

Assignment 2b. What Is Your Watershed Address?

Watershed Address

When we think about our address, we tend to think street name and town, and maybe, state and country. This address, however, is only one of our addresses. We have another one, our watershed address. To find it, locate the stream nearest to your school and/or home. Use Google maps, local maps, Gazetteers etc. to find your school. Where is the nearest stream to your school? Does it have a name? What is the nearest stream to your house or neighborhood? What river does the stream lead to? Where does the river flow? What waterbody does the river ultimately drain to?

Develop your watershed address, starting with the largest waterbody and working back to the smallest waterbody. For example, my watershed address is: the Atlantic Ocean, Chesapeake Bay, Susquehanna River, Octoraro Creek. What is yours?

Assignment 2c. Local Watershed Group

Identify and meet a local watershed group. Members of this group may become future partners for your classes.

Assignment 2d. Do it! Local Watershed Model

Make a simple model of your local watershed using materials you have available. Green Tip: Consider using recycled or repurposed materials. For fun and inspiration, watch the 15-minute NorthBay video that explains how watersheds work using the character, “RD” (Rain Drop): https://vimeo.com/264540625

Assignment 2e. Do it! How Land Use Influences Runoff

Model the effect of land use on runoff quantity and quality.
Post a picture of your model and results.

Stream Order

Look at the model you created. Do you notice that small streams flow into larger ones? Land drains into the nearest creek, that creek flows downhill to join other creeks and form larger and larger streams. Streams are classified in a specific way. A stream that has no tributaries is called a first order stream. A stream that is formed when two first order streams come together is a second order stream. A stream that is formed when two second order streams come together is called a third order stream. When two third order streams come together they form a fourth order stream and so on. The order of a stream only increases when two streams of equal order meet. The Amazon is a 12^{th} order stream, the highest order on earth. Use a map to determine the order of the stream closest to your school.

Assignment 2f. Do it! Water Cycle.

The Water Cycle. We experience it. We are part of it. We contribute to the water cycle and impact its health. Use any media to show the water cycle and *your* role in it. Be sure to include all the water cycle processes as well. Have fun with this while being scientifically accurate! Post a picture or video of your model and results for us.

Hydrology and the Physical Environment

Watersheds are a landscape level feature. Land use in the watershed dictates how water moves through the watershed, whether the majority of the water flows over land as runoff, or whether it soaks into the ground and moves through the watershed as shallow subsurface flow, or becomes part of the groundwater. How water moves through the watershed or landscape affects rivers and streams at a number of levels, including the reach level.

A stream reach is a section of stream with similar hydrologic characteristics.The reach of the stream is affected by how the channel responds to water and sediment movement. There are three kinds of flows that influence the physical characteristics of stream reaches. Base flow is the water that is in the stream without a storm event. Base flow is the slow release of surface water or groundwater that seeps into the stream bed. Base flows provide aquatic habitat because they are the source of stream water between rain events. Frequent storm flows, or bankfull flows fill the channel up to the top of its banks and are responsible for shaping the channel. They are what occur during larger rain events and typically occur about once a year in a watershed that hasn’t been modified by agriculture or development. Rare flood flows are discharges that escape stream banks and move into the floodplain, the low-lying area adjacent to the stream reach. These occur less frequently than bankfull flows but can have a big impact on the behavior and appearance of the stream channel for years after the flood event.

Riparian Zone

The riparian zone is land adjacent to streams that provides the transition between terrestrial and aquatic ecosystems. As you will see shortly, the boundaries between these two systems are porous, as materials and species flow between them. We have heard one Oregon educator say that “when you look at a tree on a streambank, you are also looking at the stream.” This is a beautiful way to describe the interconnectedness that exists between habitats.The stream doesn’t end at the bank, but continues on to give life to the trees standing on the bank.

Riparian forests, or riparian buffer zones, are critically important to water quality. They shade the water which helps keep water temperatures low. This is very important for the health of stream organisms, especially cold water fisheries, such as trout. Riparian forests also trap sediments, remove pollutants and take up nutrients such as nitrogen and phosphorus. They stabilize stream channels by providing structure. The roots of trees bind soil along the bank and help the bank resist erosion. Riparian forests help lessen floods. They give the water somewhere to go, and the trees and vegetation reduce the velocity of the water. Riparian forests interact with streams. Tree leaves provide food and attachment sites for underwater organisms when they fall into the stream. Stream macroinvertebrates that emerge from water as adults rest on nearby tree branches and trunks. When trees fall into the water, their woody structure provides underwater attachment sites and can influence water flows, thereby creating additional habitats.

Stream Features, Structures and Local Hydraulic Conditions

Features

A drainage network or watershed can be measured in hundreds of miles. A stream reach can be measured in hundreds of feet. Stream features can be measured in tens of feet or less. Some examples of features found within a stream reach include pools, glides and riffles. These features can contain smaller structures like sandbars, gravel riffles, boulder cascades and woody material. Stream features and structures influence local hydraulic conditions, creating eddies in some locations and swift turbulent flows in others. The features and structures found in the stream and the way the water flows through them form a complex, diverse, multilayered habitat, which is important for biodiversity. Different species have different habitat requirements, so diverse habitat provides the best support system for the most species. Biodiversity, or diverse life, leads to stable ecosystems. Biodiversity can also mean rich ecosystem services such as air filtration, clean water, and pollination of plants that produce food for human beings. Please study the next four photos which illustrate stream features and changes in water velocity and depth.

Figure 4. What do you notice in this photo? Can you identify different habitats?

The most obvious features in a stream reach are usually related to the changes in the slope of the stream channel which affects the velocity of the water. Changes in slope create riffles, pools and runs, and each of these affect the kinds of organisms we find.

Figure 5. A Riffle

What do you notice in this photo? Does this look like a low energy or high energy environment? Riffles are areas where coarse gravel or cobble have gathered. Water depths are shallow. The shallow, uneven bottom causes fast water velocities and turbulent flows. The spaces between the cobble provide lots of habitat for a variety of aquatic organisms.

Figure 6. A Pool

What do you notice in this photo/video? How is it different than the first one? Pools and glides are found where the stream bottom has low or reversed slope. Water depths in the pools are deeper than anywhere else in the reach, and water velocities are low compared to other places in the channel. Glides are like pools, only shallower (two to four feet deep compared to over seven feet deep for pools). Pool bottoms often are covered in sediments since the low energy environment allows them to settle out, whereas glide bottoms are often sand and gravel.

Figure 7. A Run

What do you notice in this photo? Is it similar or different from the first two? Runs are intermediate between pools and riffles and have moderate depth and flow velocities. They share characteristics of both pools and riffles.

Structures

Stream features may contain structures: gravel/cobble bars, boulders, woody material. Take a few moments to look at the three structures in the next set of underwater photos. They can be located mere feet from each other, yet they drastically impact the type and quality of life that is possible in a given location. What can you picture living in proximity to each of the following structures? How does each structure offer different benefits and/or risks to members of the aquatic community?

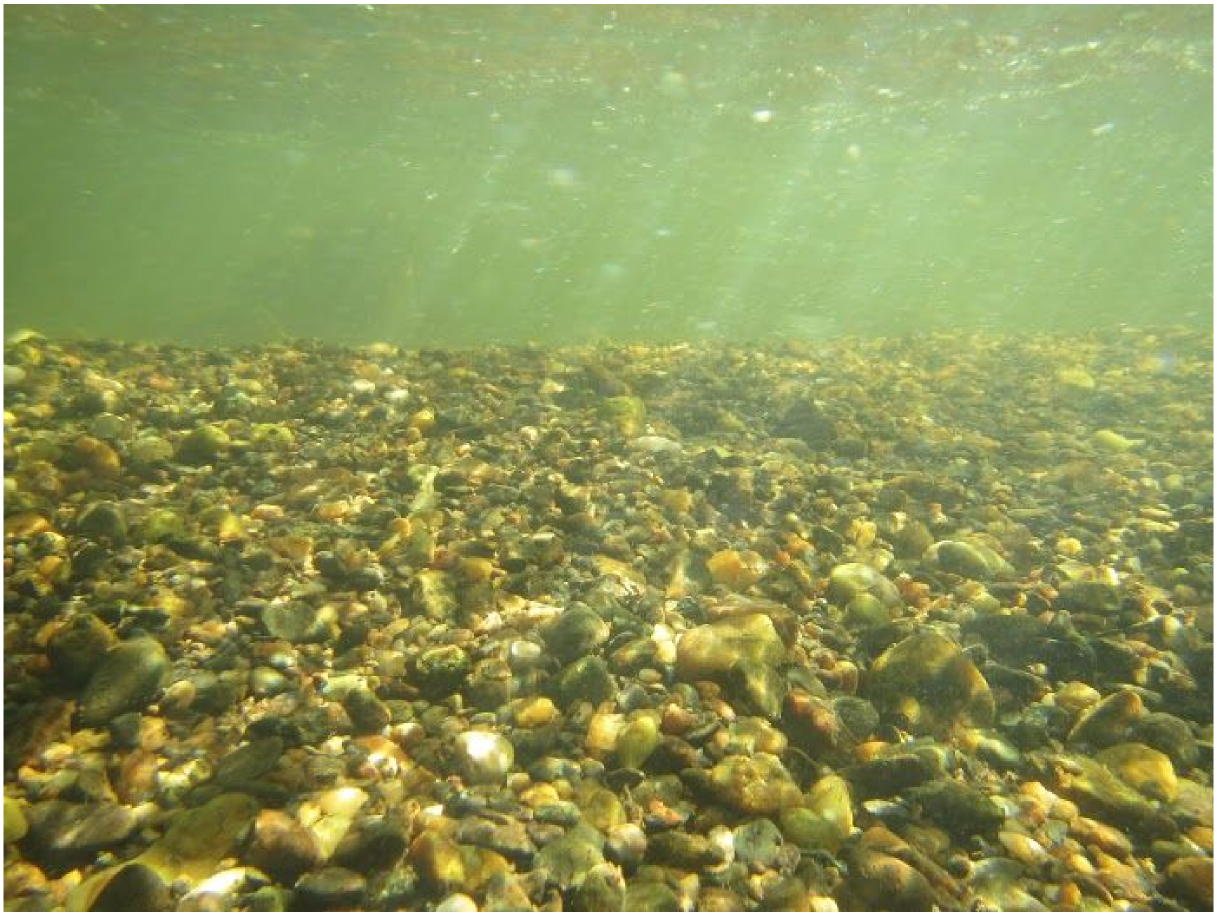


Figure 8. A Sand and Gravel bar

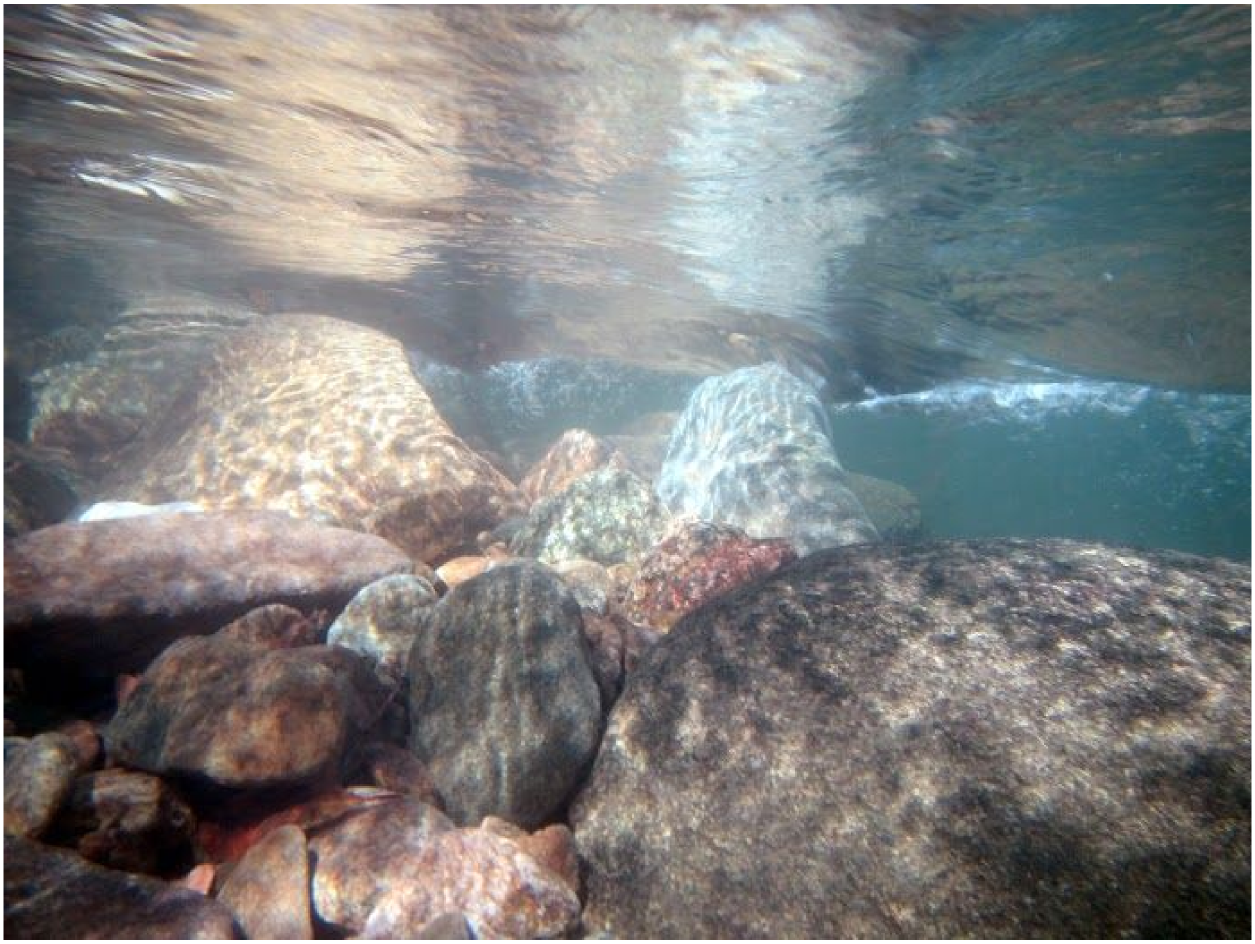


Figure 9. A Boulder Cascade

Figure 10. Woody Material

People who fish know to look for features and structures. They know that bass lurk in the shade of submerged logs. They know that trout wait at the bottom of a boulder cascade ready to snatch up dislodged invertebrates as they tumble through the water. Exploring children know that flat rocks can hide crayfish, and that an undercut bank is a perfect place to find a frog. Turtles know that a half submerged branch is a perfect place to catch some rays. Raccoons know where to find food.

Habitat features and structures affect aquatic life and shape biotic communities. Anything that affects aquatic habitat, affects aquatic life. Each feature and structure may be relatively small in size but collectively they provide texture and richness, influencing the stream reach to create a diversity of habitat for a multitude of aquatic organisms.

Each individual feature may seem insignificant, but each one is important to the organisms that need it as habitat.

Character Connection

At NorthBay, we weave character themes into our lessons. We want people to think about what they need for their own wellbeing, and how their choices and actions matter, how what they do is impactful. For this section about streams, there are natural parallels between what individual physical features, structures and species contribute to the overall health of the stream, and what people contribute to human and other ecological communities. Take a moment to consider the roles (your niche) you play in your family, community, and local and global environments. Consider how significant they are. Consider how impactful they are.

Local Hydraulic Conditions

There can be localized changes in flow conditions within a reach due to the effects of structures and abrupt channel transitions. Structures such as large rocks and roots that stick into the channel can cause changes in flow.

Watch the 30-second video *North Creek Eddy*: https://vimeo.com/261377048
What do you notice about this video? Do you wonder how that material is swirling in the water? Eddies are formed when the main flow is deflected around an obstruction, like a rock. The deflection causes a lower pressure spot on the downstream side of the obstruction and the water recirculates from a downstream to upstream direction into that low pressure spot. Swirling water behind the obstruction results and there is often much less water velocity behind the obstruction. Eddies provide habitat for some organisms.

Figure 11. Hogsucker

Watch the 1-minute video, *Climbers Run Hogsucker*: http://vimeo.com/261348546

What do you notice in this photo/video? Do you see that fish vacuuming up sand on the bottom? What do you wonder? Sand and gravel bars form when sand, gravel or cobble accumulate due to water flow. Bars often form in slower water like behind large rocks or on the inside of bends, where water velocities are lower. Bars provide habitat to animals adapted for life on a sandy bottom. For example, hog suckers vacuum food from sands and gravels.

Watch the 35-second video, *Passage Creek Bass*: http://vimeo.com/261353898

What do you notice about this photo? Do you see the fish tail sticking out of the hole in the clay bank? What do you wonder about that? Clay banks form when the stream cuts down into underlying clay. These clay banks can also provide habitat to a variety of organisms. Crayfish burrow, and sometimes, fish carve out homes.

The physical features and structures in a stream play an important role in the food web by influencing the spatial and temporal availability of habitat for food, reproduction and predation avoidance. The primary biological communities in a stream ecosystem are bacteria, algae/diatoms, macroinvertebrates and fish. Different species have different habitat requirements for successful reproduction and development across their life spans. Each species has a role to play in a stream's food web.

Food Webs

Fifty percent of the food that fuels a river ecosystem generally comes from outside of the river in the form of leaf litter and other organic debris that falls in or washes into the stream. Streams must have the right features - such as rocks and eddies - to capture this imported food. The other half of the food comes from algae. The microscopic community plays an important role in the ecology of the stream, either through the direct production of food via photosynthesis in the case of algae, or through decomposing organic materials that fall into the stream in the case of bacteria. Algae and diatoms tend to use the hard substrates found in streams. Algal and diatom community richness are vital to other components of the food web such as the benthic macroinvertebrates.

Benthic Macroinvertebrates: Benthic macroinvertebrates are organisms that live on the bottom of streams. 'Benthic' means 'bottom'. 'Macro' means 'big enough to see without magnification', and 'invertebrate' means 'without a backbone'. Organisms like caddisflies, mayflies, clams and crayfish are benthic macroinvertebrates. This group of animals is very important for stream health and for processing and transforming organic matter into food for other aquatic life. Macroinvertebrates have a variety of lifestyles and feeding modes.

Shredders decompose large organic particles that fall into streams like leaves and twigs.

Grazers scrape algae and diatoms from rocks and other substrates.

Collectors filter fine particles transported from upstream.

Predators feed on other animals. The more diverse the features of the stream, the more diverse the macroinvertebrate community.

Aquatic Diversity

Healthy streams typically have species from several feeding groups and lifestyle modes that inhabit different stream features available within a drainage network. Active filtering collectors, such as clams and several species of mayflies, are found in pools and runs. They are active because they move water through or around their bodies in order to collect food. Passive collectors, such as net spinning caddisflies, are found in riffles. The flowing water brings the food to them. Leaf litter in pools harbor shredders such as amphipods. Shredding stoneflies inhabit leaf packs trapped in riffles and runs. The slow moving water of pools is home to predatory dragonfly larvae, while predatory stoneflies inhabit riffles and runs. Grazers such as snails and many mayfly species exist where there is a hard substrate colonized by algae and diatoms.

Fish: The physical habitat characteristics that influence the macroinvertebrate community also influence the fish community. A stream with diverse habitats will likely have a diverse fish community. Similar to members of the macroinvertebrate community, different species of fish are adapted to occupy different features in the stream. For example, suckers are well adapted to glean food from soft sediments in pools and runs, while predators like trout and bass use hiding places provided by woody debris and large rocks to ambush prey.

Assignment 2g. Discover Local Stream and River Issues

1. Google the name of your local stream/river and see what comes up. Use the keywords: issues, environment, water quality, dams, sedimentation or invasive species in conjunction with your local river name google search.

2. Make an issue notebook or online folder by compiling issue articles from newspapers and magazines online or in print.
3. Keep a journal of environmental issues reported on television, the internet, and radio.
4. If you haven't already, contact river based organizations, such as local riverkeeper/waterkeepers, watershed associations, local Trout Unlimited chapters, or other environmental organizations.

Develop a list of river related issues you are interested in investigating. Later on we are going to take this list and compare it to other information you'll collect to identify a river issue to research.

My River Issue List:

Summary

Land and water, humans and streams, physical features and biotic communities; all are intimately and irrevocably connected. Human activity on land changes runoff patterns and can increase or decrease pollution. Runoff quantity and quality impact the stream channel, shaping the reach, crafting the features. Stream features and structures impact microscopic life, which form the base of the aquatic food web. Changes in features change the ability of benthic macroinvertebrates and fish to thrive. Healthy biotic communities and low levels of pollution make our water safe to enjoy, safe to sustain our lives. We are all connected.

Stream Visit

Estimated time for this stream visit: 1 hour
What you'll need: Journal, regular and color pencils, something to sit on.

Contemplate: Sit Spot Visit 2

On your way to the stream, notice how water flows over the landscape during a rain. Where does it go when it hits a roof, a parking lot, or a sidewalk? Do you see piles of soil that have been carried and deposited by water? Do you see where the water enters storm drains? Do you know where the storm drains empty? Follow them as best as you can. See if any runoff enters your stream.

When you arrive at the stream listen and look carefully. Notice the sound of the stream and how it changes. Notice the surface, where it is smooth and calm, and where it is fast flowing. Notice structures like logs, rocks. Look for swarms of insects above the water, leaves from nearby trees falling in the water. When you are done noticing with your senses, move to the reflection activity, where you'll sketch and label the stream features, structures and food webs you learned about in Tributary 2.

Reflect. Sketch Your Stream.

Sketch your stream. Add lots of details, including the stream soundscape. Where is it gurgling, bubbling, silent? Where is the water running smooth, and where is it turbulent? Label riffle areas, pools, runs, glides, and structures, such as boulders, cobbles, and trees or branches in the water. Begin to sketch a food web, as best you can. You'll fill in more details later, after completing a stream assessment in Tributary 3. Consider what is happening beneath the water surface as you complete this reflection.
Extension: After sketching your stream and labeling features and structures, pull out your phone and record the stream sounds, the stream music. Share the recording with someone else. Listen to the recording when you can't get to the stream but need a respite.

Interlude 2

I wonder about your story.

From where did you come?

What did you experience in your life?

How long did you live?

From what did you build your exquisite self-made home?

How did you know how?

From an irritant

You create a pearl.

You are an invertebrate

Your remains common on our beaches

And yet . . .

You are so much more.

I wonder

what else your home will become.

– K. Chambliss & S. Palko