ROCK PACK MANUAL

Exploring Ecosystem Engineers with the Rock Pack Experiment

STROUD WATER RESEARCH CENTER

NSF

MONTANA STATE UNIVERSITY

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This chapter includes both printable data sheets and example data sheets. Data sheets with an asterisk* are strongly recommended for a successful Rock Pack Experiment. All others are optional extensions.

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CHAPTER 1: INTRODUCTION

The Rock Pack Experiment

The Rock Pack Experiment combines topics in environmental science, technology, engineering, and math (E-STEM) with freshwater ecology and geomorphology through the unique world of the **net-spinning caddisfly** (Order Trichoptera, Family Hydropsychidae). For gathering water quality data for monitoring purposes or for teaching the scientific method follow the procedures outlined in Chapter 2. To further extend the rock pack experience with students for learning about macroinvertebrate identification, stream geomorphology and more, see Chapter 3.

Now back to Caddisflies! During their larval lives underwater, this group of globally distributed aquatic insects spin silk mesh nets that they use to filter feed. The silk mesh nets are important ecosystem engineering structures in flowing waters that can regulate sediment erosion, provide natural flood control, and enhance habitat availability for other macroinvertebrates (Cardinale et.al. 2004; Albertson et al. 2014; Albertson et al. 2019; Tumolo et.al 2019).

The Rock Pack Experiment includes interdisciplinary, inquiry-based, and hands-on activities that can be used indoors or outdoors in a middle or high school lesson plan and that equip students with E-STEM skills with real-world research applications. Each Rock Pack experiment has the same outcome:

- To provide an understanding of the structure, function, and adaptations of freshwater macroinvertebrates, with an emphasis on the net-spinning caddisfly larvae, within a stream community and the greater ecosystem
- To relate the abundance of net-spinning caddisflies colonizing artificial rock packs to:
  - fluvial geomorphological features, including the influence of silk and ecosystem engineering on sediment erosion, streambed stabilization, and flood control
  - the general ecological health of the stream community

Students study these incredible larvae by creating artificial "**rock packs**," or dry rocks in mesh bags that simulate the naturally available rock habitat found in a stream riffle area. By filling the bags with gravel (sizes 10-60 millimeter) at weights between 1,000-3,000 grams, participants provide ideal habitat for net-spinning caddisfly retreats. Packs are left in the stream for three to four weeks, during which they are colonized by macroinvertebrates. Participants then quantify the relative abundance and diversity of the macroinvertebrates with a special focus on net-spinning caddisfies, either back in the classroom or streamside as an outdoor field experience.

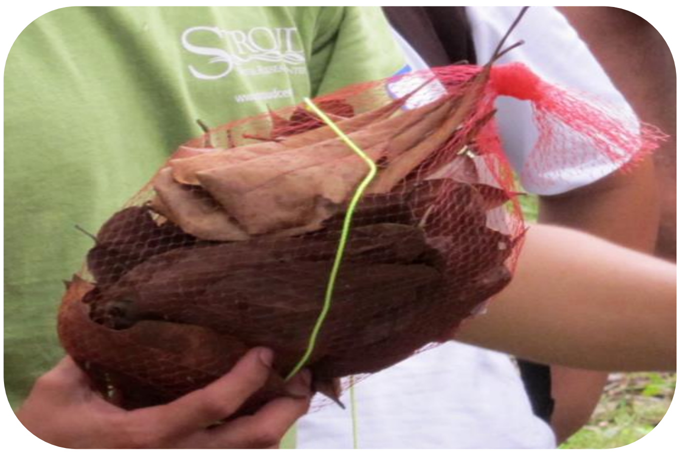
How do I get involved with the Rock Pack Experiment?

- ✓ Rock Pack Manual
- ✓ Materials to conduct the experiment listed in Chapter 2 and 4 and printable data sheets from Chapter 5
- ✓ Access to the internet with a computer or smart device, such as a phone or smart pad
- ✓ A stream that is safely accessible

For more specific information on how to become a part of the Rock Pack Network or to determine the availability of a workshop in your area, contact the Leaf Pack Administrator (the Rock Pack Experiment is an extension of the Leaf Pack Network) at: leafpacknetwork@stroudcenter.org

A Rocky History: Origin of Rock Pack

Leaves form natural "packs" in streams year-round.



Artificial leaf packs provide unique learning opportunities.

In 1989, a scientist at Stroud Water Research Center (Stroud Center) was invited to his daughter's ninth grade classroom to conduct a lesson on streams. The stars of the show were **"leaf packs,"** or dry leaves in a mesh bag that mimic the natural process of leaves forming packs in streams. The scientist thought leaf packs would be an easy way to not only bring macroinvertebrates to the classroom, but to engage the students. He was right, and thus was born the Leaf Pack Network®.

Today, the network of citizens, teachers and students continue to use leaf packs to investigate their local stream ecosystems. By using the Leaf Pack Network Stream Ecology Kit sold by the LaMotte Company and original curricula by Stroud Water Research Center, participants enhance their understanding of stream ecosystems, learn scientific principles, and demonstrate the importance of streamside forests. The resources and activities available through the network are valuable tools for establishing baseline water quality conditions and periodic monitoring of a local waterway.

In 2016, scientists and educators from Montana State University and Stroud Water Research Center began exploring the role of net-spinning caddisfly larvae (Order Trichoptera, Family Hydropsychidae) in stream erosion regimes. Funded by a Division of Environmental Biology Ecosystem Studies grant funded by the National Science Foundation, the collaborative research focused on how silk webs created by the crafty critter bind together gravels on the riverbed. By 2017, this partnership launched an exciting extension of the Leaf Pack Network: the Rock Pack Experiment. The team discovered that like leaf packs, rock packs simulate natural processes in healthy streams while creatively engaging everyday citizens and students in freshwater science. The new programming integrated many of the concepts that make leaf packs powerful learning tools, such as the role of freshwater macroinvertebrates in food webs and water quality. However, its focus on the net-spinning caddisfly integrated new topics like ecosystem engineering, fluvial geomorphology, sediment erosion, and flood control to create real-world connections between land use and water quality.

NOTE: The Rock Pack Manual provides a brief summary of freshwater macroinvertebrate fauna, but its focus is the net-spinning caddisfly. For more information on macroinvertebrates' unique life cycles, functional feeding groups, and roles as water quality indicators, please visit the Leaf Pack Manual on the Leaf Pack Network website: https://leafpacknetwork.org/resources/manual/.

Linking Rocks to Streams

All **ecosystems** rely on the steady supply of energy or nutrient cycling, and streams are no exception. Pick up any rock from a streambed. On its surface you can discover a complex network of energy, including slimy detritus from leaves swept downstream; tufts of aquatic plants like algae; creeping, crawling macroinvertebrates (e.g., insect larvae, crustaceans); and assemblages of microorganisms or microbes (e.g., fungi and bacteria) undetected by the naked eye. Each play a critical role in producing or processing the flow of energy through the system.

As students, we often learn that this system begins with the sun. Solar energy drives photosynthesis, which supplies carbon (chemical energy) for the rest of the system. In many small, densely forested streams, however, sunlight cannot reach the water's surface due to shading from the forest canopy. Leaf fall from the forest canopy prevails as the dominant food resource for these small streams, supplying much of the carbon needed to support the stream throughout the year. As leaves fall or are blown into the stream, they float downstream until catching on rocks; the more rocks in a streambed, the greater the surface area for leaves to become trapped and accumulate in natural "packs." After a few weeks of submersion, the leaves become slimy with the colonization of fungus and bacteria (decomposers) and, in time, are colonized by many macroinvertebrates.

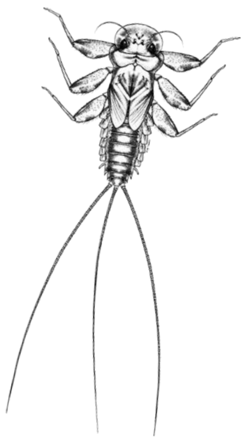
Riffle sections harbor a diversity of stream life and are ideal locations for net-spinning caddisfly colonization.

Rocks likewise play an important role in the freshwater food web. Rock surfaces in streams can form blankets of algae and biofilm, a matrix of freshwater microbes, sand, and silt. Algae and biofilm on rocks provide important food sources, acting much like peanut butter on a cracker for hungry macroinvertebrates. Here, rocks of varying density and grain size provide important shelter and **habitat** for macroinvertebrates, fish, and other aquatic fauna. Rocks are important physical features of the healthy streams that offer many different types of habitats, which in turn support aquatic animals specially adapted to certain niches in each of those different habitats.

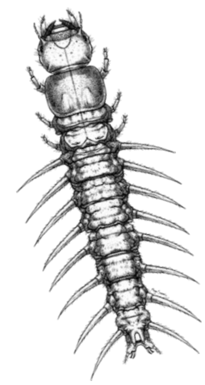
For example, **riffles** (shallow, fast-flowing, rocky areas) characteristically offer diverse environments, and the fast-flowing water offers a continuous supply of oxygen and food to macroinvertebrates. Slow-flowing, muddy-bottomed habitats, such as pools, facilitate a very different habitat; they support macroinvertebrates adapted to these specific conditions and contain different species compared to the macroinvertebrates found in riffles. Other stream habitats to investigate include sandy/silty bottoms, areas near vegetated banks, and areas having an accumulation of woody debris. Each habitat type may offer a unique assemblage of macroinvertebrate species, and the density and grain size of the rocks present in each habitat further determine which specially adapted macroinvertebrates has moved into the neighborhood.

Freshwater Benthic Macroinvertebrates

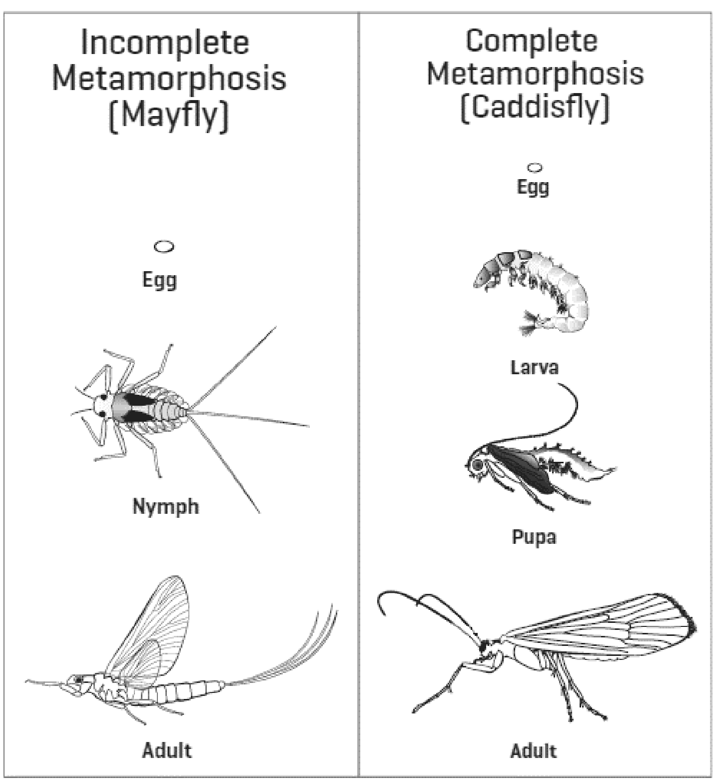
Once a rock pack has been submerged in the stream for several weeks, algae may begin to grow, detritus (dead particulate organic material) like leaves may accumulate in packs behind the rocks, and microbes (decomposers like bacteria and aquatic fungi) will begin to colonize the rocks' surface. Slimy biofilms, a matrix of freshwater microorganisms, sand, and silt, may coat the rocks' surface. Soon, **benthic freshwater macroinvertebrates** also enter the rock pack to discover new habitats beneath and between the rocks, feed off of the algae, and further break down detritus. Benthic freshwater macroinvertebrates can be defined as the following:



Benthic	=	inhabit bottom areas/substrates
Freshwater	=	streams, rivers, lakes, ponds
Macro	=	relatively "large" (> 0.2 - 0.5 mm)
Invertebrate	=	animal without vertebrae



These macroinvertebrates play important roles in the food webs of the stream ecosystem, but algae and detritus can be difficult for macroinvertebrates to digest and contain nutrients that are hard to absorb. The aquatic fungi and bacteria that colonize the rock packs act as a first step in the decomposition process and provide an essential component to the macroinvertebrate diet.



Many macroinvertebrates are aquatic insects that go through several stages from egg to adult. The number of stages depends on the type of metamorphosis, or the series of developmental changes, the insect follows. Insects that undergo **incomplete metamorphosis** follow three stages. They begin as eggs that hatch into **nymphs**, which then grow into adults. The immature period is called the nymphal stage. Examples of insects that undergo incomplete metamorphosis are mayflies, dragonflies, damselflies, stoneflies, and true bugs. Many of the insects that undergo incomplete metamorphosis are aquatic only during the egg and nymphal stages. The winged adults do not live in the water. Dragonflies, for example, can often be seen in the adult form flying along streams and rivers in the summer.

Insects that undergo **complete metamorphosis** have four stages: egg, larva, pupa, and adult. They begin as eggs that hatch into tiny **larvae**. The immature period is called the larval stage. These larvae grow and eventually enter a pupal stage, in which the insects are transformed into an adult. Many are familiar with the complete metamorphosis of the butterfly, during which a caterpillar (larval stage) emerges from a chrysalis (pupal stage) as a fully transformed butterfly (adult stage). Examples of aquatic insects that go through complete metamorphosis are true flies, beetles, dobsonflies, and the focus of the Rock Pack Experiment: caddisflies.

Many insects that undergo complete metamorphosis are aquatic during the egg, larval, and pupal stages, but not as adults. However, some insects like the whirligig beetle and predaceous diving beetle pupate out of the water into overhanging tree branches, and others like the whirligig beetle and predaceous diving beetle also return to the water as adults.

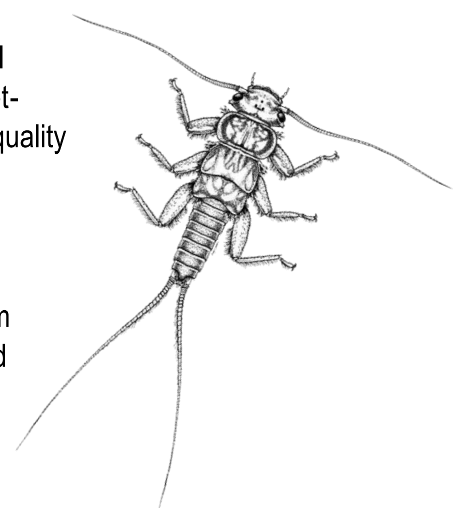
The majority of insects found in the rock packs will be in the nymph or larval stage, with the total life cycles of macroinvertebrates ranging from less than two weeks for some true flies (e.g., midges and mosquitoes), to two years or longer for some stoneflies, dragonflies, and dobsonflies.

Water Quality Indicators

The ability of freshwater macroinvertebrates to flourish not only depends upon optimal physical factors, but also on chemical factors in their environment. Many macroinvertebrates require a specific range of chemical parameters (pH, dissolved oxygen, temperature, alkalinity, etc.) to survive. Generally, unpolluted waters support a greater variety of freshwater macroinvertebrates than polluted waters. Some tolerant macroinvertebrates can tolerate polluted waters, and these may be found in a greater abundance in polluted waters than in unpolluted waters.

Other macroinvertebrates, meanwhile, are highly sensitive to pollution and habitat disturbance, meaning they typically cannot survive polluted waters. As “canaries of the stream,” these organisms function as living barometers that indicate changes in water quality. Therefore, macroinvertebrates act as **bioindicator organisms** whose presence or absence in a stream can be used to estimate the **water quality** and the overall health of the stream community. Wherever you are in the world, macroinvertebrates can paint valuable portraits of stream communities, water quality, and watershed health.

On the spectrum of pollution tolerance among macroinvertebrates, organisms may fall roughly in between tolerant and sensitive. These macroinvertebrates, including the net-spinning caddisfly, are facultative or semi-sensitive, meaning they prefer good water quality but are somewhat tolerant of impaired water.



Please note that because streams are complex ecosystems, a combination of macroinvertebrate, chemical, and physical data provides the most comprehensive assessment of the stream. When introducing artificial rock packs to a particular stream environment, it is informative to supplement macroinvertebrate data with chemical and physical data using a variety of field test kits and visual surveys.

Functional Feeding Groups

Macroinvertebrates can be divided into groups, known as **functional feeding groups**, based on their feeding methods and adaptations. In a simplified view of the food web, these groups process detritus in a stepwise fashion. Large detrital pieces and their associated microorganisms (fungi and bacteria) are eaten by certain, highly specialized macroinvertebrates. This “eating” process yields smaller particles (feces and leaf fragments), much like “crumbs” created after eating crackers, that provide food for other functional feeding groups further downstream. These macroinvertebrates, in turn, are an important food source for predators. Ecologically, the macroinvertebrates are a primary link between the base of the food web (algae, detritus, microorganisms) and larger animals like fish.

The shredders are the first group of macroinvertebrates to break down large organic material like leaves. Shredders (which include crane flies, some caddisflies and stoneflies, sowbugs, and scuds) break the leaves down into fine particles by eating them. Drifting downstream, the fine particles become food for another group of detritus feeders, the collectors. Collectors use various methods to filter or gather the fine particles. Gathering collectors include some mayflies and midges. **Filtering collectors**, such as the black fly, use fanlike filaments near the mouth to capture food particles. **Other filtering collectors, such as the net-spinning caddisflies, construct web-like nets.**

The grazers (also known as scrapers) are another group of freshwater macroinvertebrates present in the stream community. However, these organisms feed on the algae that grow on the surface of rocks. They include some caddisflies, the water penny (a beetle), and certain midges and mayflies. The shredders, collectors, and grazers are food sources for predators, which include other macroinvertebrates such as dobsonflies and the dragonflies. Predators have large, powerful mouth parts used for grasping prey. All macroinvertebrates, in turn, are food for fish and birds.

Feeding Strategy	Food Category
I. Shredders	dead leaves/live macrophytes
II. Collectors	fine organic particles (live/dead)
Filter Feeders	particles in water column
Miners	buried particles
Browsers	bottom surface deposits
III. Scrapers	live benthic algae (diatoms)
IV. Piercers	live filamentous algae
V. Predators	other invertebrates + small fish

Macroinvertebrates are classified based on feeding adaptations and/or food preferences.

For a more detailed look at functional feeding groups and their relationship to stream size in the watershed, please visit: https://www.leafpacknetwork.org/learn/linking-trees-streams.

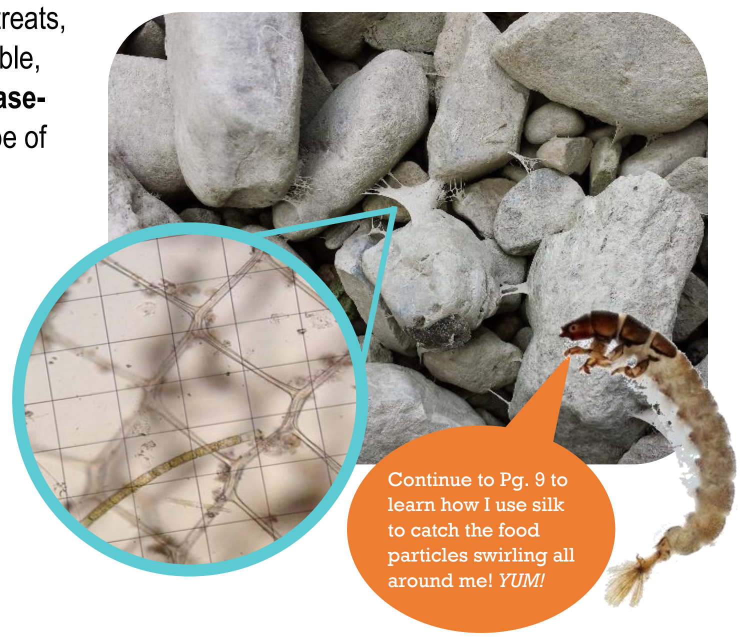
Life History of the Caddisfly

The northern caddisfly (Family Limnephilidae) spends its larval stage (A) underwater as a case-builder, using sticky silk to construct portable cases from plant and mineral materials. It spends its adult stage (B) on land.

Caddisflies (Order Trichoptera) are a highly advanced and diverse group of macroinvertebrates that live in fresh water for part of their life cycle. Caddisflies spend their egg, larva, and pupal stages in water (aquatic), before undergoing complete metamorphosis into a winged adult that lives on land (terrestrial). Closely related to butterflies and moths (Order Lepidoptera), caddisflies earn their names from their characteristic adult wings, which possess small hairs rather than the scales seen in butterflies. In the scientific name for this special insect order, *trichos* means "hair" and *pteron* means "wing."

This caddisfly life cycle typically includes one generation per year, with new adults sometimes emerging in large numbers to mate on vegetation or rocks near water and to deposit eggs directly in the water. As aquatic larvae, caddisflies are adapted to an incredible array of microhabitats in streams and lakes alike with varying substrates. In streams and rivers, caddisfly eggs, larvae, and pupae often inhabit rocky streambeds in fast-flowing riffles. Here, the sediment ranges from the size of your thumbnail to the size of large boulders. The turbulent water is rich in **dissolved oxygen** and helps water temperatures remain relatively cool. Meanwhile, natural leaf and rock packs in the riffle provide important food and shelter for the caddisflies.

From family to family and species to species, the larvae are highly specialized in their underwater behaviors. Most are classified by scientists as sedentary or as crawlers, but scientists classify many others as burrowers or active swimmers. Due to their incredible diversity, caddisflies play a pivotal role in freshwater food webs, with different kinds adapted for shredding, collecting, grazing, scraping, or even predation on fellow macroinvertebrates. Perhaps the behavior caddisflies are most known for is silk production. Emitted from their mouths at the tip of the labium, the **caddisfly silk** functions like sticky, stretchy, waterproof tape for the complex creation of cases, retreats, nets, and cocoons. Caddisfly groups that use silk to craft portable, protective cases from small rocks and detritus are known as **case-building caddisflies**. Read on to discover another exciting type of caddisfly!



TECHNOLOGY CONNECTION!

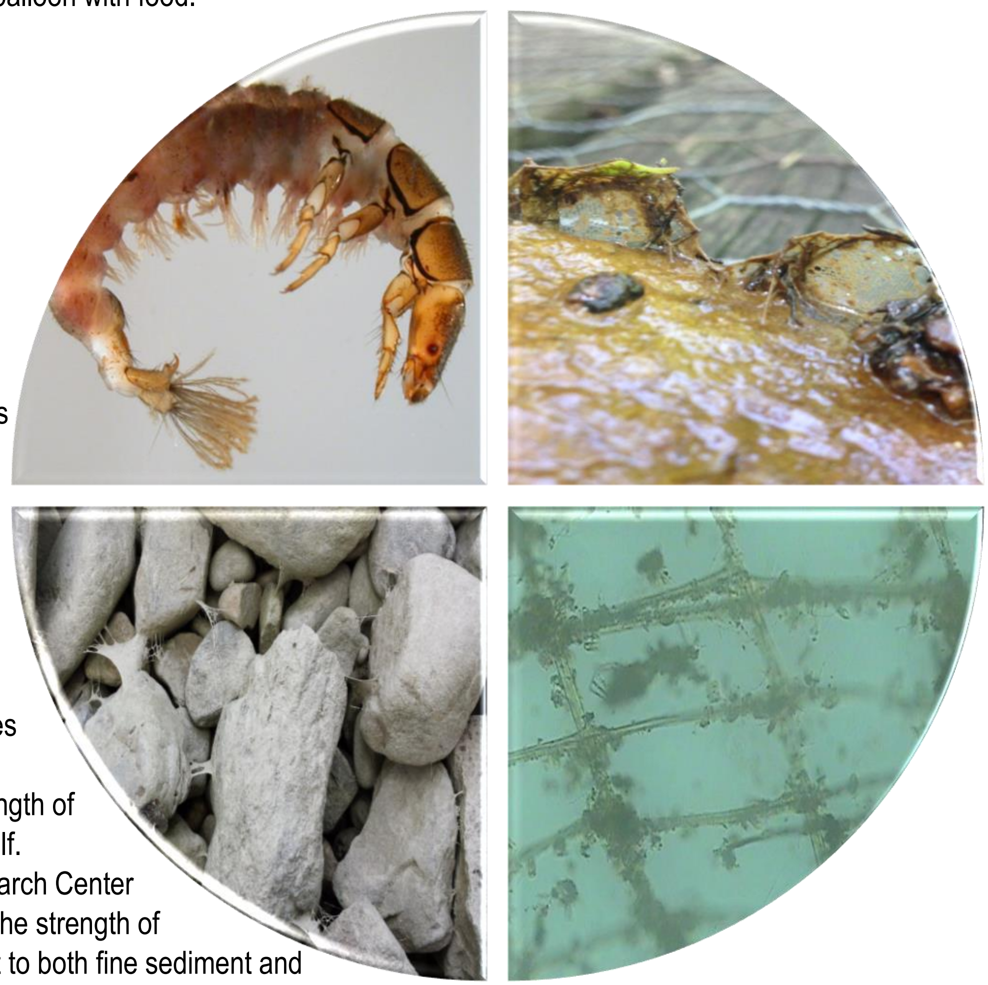
For a digital introduction to caddisfly ecology, watch this video lecture by Dr. Lindsey Albertson:
https://youtu.be/lt9MxtzGCDY

Looking for a shorter video that creatively engages all ages in the wonders of caddisfly silk? ROCK OUT to this 4-minute video by PBS Digital Studios!
https://youtu.be/Z3BHrzDHoYo

The Craftiest Critter: The Net-Spinning Caddisfly

The Rock Pack Experiment focuses on the **net-spinning caddisfly** (Family Hydropsychidae), a group of globally distributed aquatic insects and the most abundant caddisflies in many parts of North America. This crafty critter produces its own silk for a clever purpose: to trap and eat its food. Similar to how a spider catches food in silk webs, net-spinning caddisfly larvae use a homespun net to capture food from the water column. The nets resemble strings in a tennis racket, with each silk thread placed into just the right spot to create mesh webbing that will stretch and balloon with food.

But what is on the menu for the net-spinning caddisfly? As a filtering collector and ominivore-detritivore during at least part of its larval stage, the animal uses a feeding strategy called filter-feeding to pull suspended particles, such as broken-down leaf detritus and even animal parts, out of the stream and into its net. It then uses its mouth to feed directly off of the silk – no silverware needed! This feeding strategy is similar to how a mussel or oyster pulls water over its gills to filter-feed suspended particles.



Many types of net-spinning caddisflies call streams home, and each one can build a different type of silk net. Individual species vary in the silk they produce, including the number of silk threads in their net, the strength of the silk threads, and the size of the net itself. Moreover, scientists at Stroud Water Research Center and Montana State University have found the strength of net-spinning caddisfly silk is highly resilient to both fine sediment and drought (Albertson et al. 2019).

Even among different species, the silk maintains its overall structure and strength under both stressors. As streams worldwide experience record flooding and drought due to climate change and human impacts, the research points to caddisfly silk as a potentially powerful tool in the recovery of aquatic communities after short-lived disturbances (Cardinale et al. 2004, Tumolo et al. 2019).

The larva doesn't only use its silk to catch dinner. When it is not harvesting food from its net, the animal hunkers down in its **retreat**, or a crude dwelling crafted from rock and/or detritus fragments and bound together with sticky silk. The silk helps each building block adhere to another, while also anchoring the retreat to rocks or woody debris so the caddisfly's shelter is not swept downstream by the swift current. Tucked inside its retreat and sheltered from predators, the larva can send its silk net billowing out of one open end of the retreat when appetite strikes. Particles floating downstream are quickly ensnared in the net's sticky strands, a key reason the caddisflies require flowing water for their special feeding method.

The larva may not be the only inhabitant of its tiny house. When abandoned by a larva, a retreat often becomes food or shelter for another macroinvertebrate.

FUN FACT! The silk threads produced by net-spinning caddisflies play an important role in modifying erosion and water flow in the stream. Keep reading to find out how!

A net-spinning caddisfly larva climbs out of its retreat after the rock the retreat is adhered to is removed from the stream

Fluvial Geomorphology

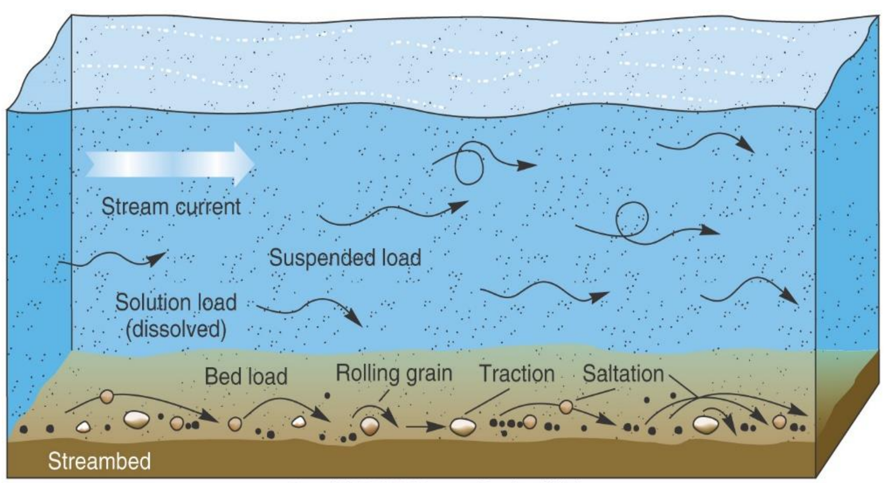
TECHNOLOGY CONNECTION!

For a digital introduction to fluvial geomorphology, watch this video lecture by Dr. Lindsey Albertson: https://youtu.be/MtJyYywarE0

Fluvial geomorphology is a scientific discipline that studies the physical shape of rivers and the processes that change them over time. The shape of a river is important because it is the home, or **habitat**, for all living things in a river ecosystem. The shape of a river determines how water flows through it, how water influences organisms like fish and macroinvertebrates, and what the water quality will be. Patterns of channel shape and sediment size are driven by the geology or rock type of the area, the river channel's location in the watershed, how steep the slope is, land use in the watershed, and the local climate.

Rivers are essentially transportation pathways for water and sediment. In the highest points of a **watershed**, large amounts of sediments are generated by hillslope erosion, delivered to stream channels, and broken down into smaller pieces as they are carried downstream. As more streams combine and the slope declines, the sediment size in rivers also decreases, and a lot is stored in riffles and in floodplains. Eventually the sediment size in the river declines as it reaches sea or lake level, where sediment is deposited into long-term storage in very large floodplains and in coastal deposits like deltas, beaches, barrier islands, and the ocean/lake floor.

In the headwaters and transport zones, sediment is often sorted into distinctive habitat features called pools and riffles. Riffles are temporary storage zones for gravels and cobbles, and they also form very important habitat for specialized macroinvertebrates, fish, and other aquatic animals that live amongst the gravels and cobbles. The water is typically shallow but fast in riffles, while it is slow and deep in pools. The sediments stored in riffles do move during large flow events as **bedload**. This term refers to gravels and cobbles that are rolled, hopped, pushed, and pulled along the bed of the river – these rocks are too heavy for the water to actually lift up into the flow for more than a few seconds.



E-STEM CAREER HIGHLIGHT

Watch a 1-minute video on the daily life of a fluvial geomorphologist: https://youtu.be/OteypmM5yeY

Melinda Daniels, Ph.D. (left), associate research scientist in the fluvial geomorphology group at Stroud Water Research Center, and Lindsey Albertson, Ph.D. (right), assistant professor in the Department of Ecology at Montana State University, are the principal investigators of a project on ecosystem engineering by net-spinning caddisfly larva.

This process of sediments being broken down by natural agents like water and wind, or **erosion**, is a very important process in river ecosystems. As humans alter land use around rivers or climate in ways that change water flow patterns and flooding regimes, understanding erosion helps us understand how to keep our streams healthy. In fact, two of the most common consequences of land use and climate change are 1) increased fine sediment loads, and 2) shifts in hydrological regimes in freshwater ecosystems (Richter et al.1997). To put it simply, erosion, flooding, and drought are big problems for the health of our streams. A growing number of studies indicate that these environmental stressors will likely have direct effects on the **species composition** (the identity of all the different organisms that make up a community) and **biodiversity** (different kinds of specialized organisms in an ecosystem) of life in our streams. Little is known, however, about how biological structures produced by aquatic organisms will respond or recover.

Ecosystem Engineers

Scientists at Stroud Water Research Center and Montana State University are working to improve that knowledge through research on **ecosystem engineers** (Jones and Shachak 1994; Moore, J.W. 2006), or animals or plants that maintain, modify, or create habitats. The animals can do so through their everyday activities. These organisms live in all types of habitats, but are especially important in rivers. Crayfish that burrow for food, beavers that build structures like dams, and plants that produce root networks that stabilize and hold together sediment on riverbanks are all well-known examples of ecosystem engineers.

Less-well-known ecosystem engineers are net-spinning caddisflies. Recent studies have found that the biological structures produced by caddisflies – silk mesh nets – have an important influence on the geomorphology in flowing waters. To the very hungry caddisfly's benefit, silk increases food particle delivery by altering near-bed current velocities (Albertson et al. 2014; Maguire et al. 2020). The benefits of silk extend to the entire stream community and ecosystem. On the riverbed, the silk threads bind together rocks as large as an orange! This reduces sediment erosion, helps regulate flooding impacts, and enhances habitat availability for other macroinvertebrates. Sometimes, the density of caddisflies can be greater than 10,000 individuals in one square meter. In cases like these, the silk nets have a particularly strong influence on reducing rock erosion and increasing how stable the rocks are. Did you ever realize that the handiwork of animals so tiny could have such big impacts?

TECHNOLOGY CONNECTION!

For a digital introduction to ecosystem engineering by net-spinning caddisflies, watch this video lecture by Dr. Lindsey Albertson: https://youtu.be/1MphNwavLgE

Looking for a shorter video that creatively engages all ages in ecosystem engineering by net-spinning caddisflies? ROCK OUT to this 4-minute video by San Francisco State University, Montana State University, and Stroud Water Research Center! https://vimeo.com/273597362

CHAPTER 2: MONITORING WITH ROCK PACKS

Materials List

Please see each section below for exact quantities and uses of items. Items are listed below to correspond with the Leaf Pack Network kit of tools (e.g. dichotomous key, macroinvertebrate sorting sheet, plastic mesh bags, etc.). See Resources section of Chapter 4 for more information and direct purchase links on the below items.

Plastic mesh bags*
Waterproof bag tags*
White plastic trays*
White plastic spoons*
Sieve*
Macroinvertebrate ID key*
Macroinvertebrate Sorting Sheets*
Scissors*
Thermometer*
Brightly colored nylon string*
Paintbrushes*
Petri dishes*
Steel rebar
Luggage scale
Waterproof marker
Pencil
Metric ruler (in mm)
Buckets
Calipers (optional)
Rocks of sizes 10-60 mm
Data Sheets (Chapter 5)

Additional Recommended Items for Macroinvertebrate Care:

- ✓ Ice Packs
- ✓ Aerator/Bubbler(s)

*The Leaf Pack Experiments Stream Ecology Kit provides these materials and can be found on the LaMotte website. For more information, please visit: https://leafpacknetwork.org/resources/equipment/.

Safety

Safety and health are import factors to consider when planning to monitor with leaf packs. Below are tips that will help you to ensure that the experience is enjoyable and safe.

- Follow all school or organization safety rules and guidelines regarding laboratory and outdoor activities.
- Follow state or country regulations for collecting macroinvertebrates. A fishing or collecting license may be required if macroinvertebrates are considered to be fish bait in your state.
- Ensure that the sampling site is on public property or if stream access is on private property make sure that permission is obtained.
- The stream or river site should be wadeable. Do not enter a waterway where the water level is no higher than your knees. When working in streams, take special care to avoid slipping and falling into deep water.
- When working near deep or fast-moving water, wear a personal flotation device.
- On cold or windy days, it is especially important to provide dry clothes or blankets in case someone gets wet.
- Check weather reports and schedule field activities accordingly.
- If lightning is seen or thunder is heard, do not work in or near the water. Go indoors immediately.
- If the water quality is uncertain, wear protective gloves and boots when coming into contact with the water. Wash hands after deploying, collecting and processing the leaf packs.
- Never drink the water.
- Carry a first aid kit and cell phone.
- Tell someone where you are going and when you expect to return.

Additionally, please read the instructions for all procedures *before* beginning the project.

Defining a Goal

Monitoring with rock packs is a 3-4 week process and takes some time and planning. Before beginning, it is important to determine the question that will be answered and the focus of the project: the goal. Is monitoring being done to establish baseline conditions to understand the health of a stream or river, or will the results be used in a school setting to teach students about experimental design?

You can do both, and this manual is written as such for a teacher to use with students to demonstrate the scientific method process. However, action projects such as monitoring the baseline conditions of a local waterway are certainly possible and simply need to be decided ahead of time.

Selecting a Waterway to Monitor

Another consideration is to determine which waterway will be monitored or studied and whether the stream has legal access. The ideal waterway would be a small stream where rock packs can be placed in shallow riffle habitats or even runs, but not a stream with deep waters such as pools or larger rivers. A good rule of thumb is to place rock packs in shallow water where the water level is no higher than your knees.

For help in making decisions about methods, goals, and how to get started, contact the Leaf Pack Network Administrator with Stroud Water Research Center at leafpacknetwork@stroudcenter.org. The Leaf Pack Network also offers in-person 1-2 day workshops, which can be catered to specifically work with rock pack methods.

Preparing Rock Packs for the Stream

MATERIALS (See Resources page, Chapter 4.)

• mesh bags	• string/nylon twine
• luggage scales (or similar scale)	• scissors
• waterproof marker	• waterproof bag tags
• metric ruler with a 2-mm mark	• gravelometer OR calipers - optional (see below procedure for more info)
• Field Data Sheet	• Wentworth grid (see Chapter 3)

Identifying the Average Gravel Size in Your Stream via the Wentworth Pebble Count

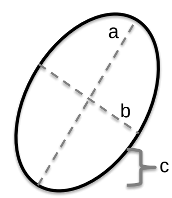
Before making packs, it is recommended you determine what gravel sizes, if applicable, that you have in your stream. The Wentworth pebble count provides a method for quantitatively characterizing the substrate particles in your streambed by determining the percentage of silt, sand, gravel, cobbles and boulders. The optional activity in Chapter 3 (Wentworth Pebble Count) will give you guidance on how to go about this process to discover your average gravel size while also understanding what percentage of the gravel is within the preferred 10mm-60mm range for net-spinning caddisfly colonization!

Collecting Rocks for Your Packs

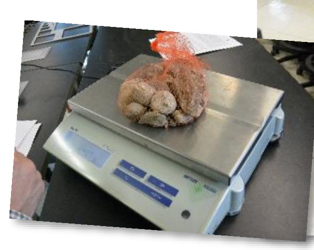
After completing the Wentworth pebble count, you can grab rocks from your stream or source them elsewhere (e.g., garden or landscape supply store). If taking gravels from your local stream, please take care and caution to not disrupt or degrade the streambed habitat, and return rocks after completing your rock pack experience. Do not remove too many rocks from any one particular area, and when removing rocks, ensure there are no macroinvertebrates removed from their natural habitat. If do you find a macroinvertebrate, gently remove the animal and place it on another rock in the same stream.

PROCEDURE

Making Rock Packs



1. Collect rocks to fill 3-4 mesh bags per stream site. It is recommended to use a combination of rock sizes between 10-60 millimeter (gravels). Measure along the b-axis (see diagram to right) with a 2-mm metric ruler (easiest option), calipers, OR use a gravelometer or Wentworth grid.
2. With a scale (e.g., luggage scale or other electronic scale; see Resources section), weigh anywhere from 500 grams (minimum suggested) to 1000 grams (maximum suggested) of rocks for each rock pack. Use an average of 750 g grams for consistency between treatments (if not manipulating weights for an experiment).
3. Record your average pack weight on the **Field Data Sheet** (see Chapter 5).
4. Complete a waterproof tag (see Chapter 4 for examples) for each rock pack, using the waterproof marker to record the following information on the tag: Bag # (e.g., 1 of 4, 2 of 4…), Site Location (e.g., stream name), Date, and any other pertinent information (e.g., group name, class, etc.).
5. Place the waterproof tag inside the rock pack bag.
6. Tie each bag closed with one knot.
7. Loop a long length of ***nylon*** twine or string through the mesh of each bag so the rock pack can be attached to a rebar post or piece of wood in the stream. See next section for more details on placing packs in the stream!



Placing Rock Packs in the Stream

MATERIALS (See Resources page, Chapter 4.)

• thermometer	• prepared rock packs
• nylon string/twine	• Field Data Sheet
• pencil	• Habitat Data Sheet
• sledgehammer	• Site Map Data Sheet
• steel rebar	• scissors

PROCEDURE

NOTE: If you are determining stream discharge, do so before placing rock packs. Follow procedures found in Chapter 3. Additionally, remember to place rock packs in shallow water where the water level is no higher than your knees, typically in a riffle habitat.

1. One tried and true method is to secure rock packs in the stream using a sledgehammer, reinforcing steel rods or rebar (1 rebar for up to 5 packs), and brightly colored (e.g., neon yellow, pink, or orange) nylon string/twine. First, use the sledgehammer to drive a piece of rebar (tall enough to see above the water level) to secure it into the streambed.

2. Loop the string through the mesh bag of each rock pack and, one at a time, tie each pack directly to the rebar and use the scissors to cut any long strings.
   NOTE: *Please remember to dispose of your waste (e.g., strings) responsibly and remove the rebar when your monitoring is completed.*

3. Position rock packs (facing upstream) so that as much surface area of the bag is facing the current as possible. Make sure all rock packs are submerged and securely tied. To further secure the rock packs, consider slightly anchoring one end of the pack with an external heavy rock found in the stream; this should NOT cover your rock pack entirely, but instead provide additional security during high flows or flooding. ***NOTE:*** *Rock packs that move with the current are not properly placed.*

4. Record appropriate information on the **Field Data Sheet.**

5. Sketch a site map on the back of the **Site Map Data Sheet** that shows the position of each rock pack in the stream and gives some guidance on how to find them as rock packs may become covered with sediment and algae making them hard to locate weeks later. ***NOTE****: It may be useful to place markers along the bank of the stream to help you find your packs again. However, these markers may draw attention to your rock pack and possibly incite vandalism.*

6. Complete the **Habitat Data Sheet**. Refer to glossary for definitions.

7. Keep the rock packs in the stream for 3-4 weeks. If possible, check the packs periodically to see that they remain submerged, especially noting if any storms occur and amounts of rainfall.

Collecting Rock Packs from the Stream

MATERIALS (See Resources page, Chapter 4.)

• thermometer	• bucket(s) (>1 gallon)
• scissors	• Field and Site Map Data Sheets
• pencil	• sieve (optional but helpful)

PROCEDURE

Mark your calendars for collecting your packs!

NOTE: If conducting an experiment with your students (e.g., comparing different rock pack grain sizes, habitat locations, etc.), be sure to keep packs separate as you collect them from the stream (e.g., in separate buckets) to ensure macroinvertebrates do not travel to other packs and cause data errors! Otherwise, multiple packs may be added to the same bucket.

1. Complete the remaining information on the **Field Data Sheet**. (e.g., time, air and water temperature, number of packs, date removed, precipitation/storm information)
   NOTE: *Refer to the* ***Site Map Data Sheet*** *to identify the location of each pack. Be sure to collect packs starting with the one furthest downstream, then work your way upstream so that you are not disturbing downstream packs as you go.*
2. Fill bucket(s) three-quarters full with stream water from the source – enough to cover the surface of your rock packs.
3. Collect additional stream water in another bucket to be used during macroinvertebrate sorting! Keep the water cool. Tap water may be used. ***NOTE:*** *Chlorinated tap water must sit for three days before use to allow the chlorine to dissipate. Chlorine will kill the macroinvertebrates.*
4. In the stream, locate your packs and one by one, cut or untie the nylon string/twine attaching a rock pack to the rebar, responsibly disposing of the string waste.
5. When retrieving a rock pack from the stream, position your bucket just downstream of your pack and bring the rock pack into the bucket quickly and gently. Some of the insects are very quick and will try to escape.
6. Repeat Steps 4-5 for each rock pack.
7. If processing rock packs indoors or storing rock packs overnight for next-day sorting, place a cooler pack and aerator/bubbler in the bucket(s). Some invertebrates are very sensitive to changes in temperature and dissolved oxygen. Therefore, try to keep the water consistently cool. Reduce stress by adding some rocks and leaves as habitat.

TIP! HOW DO I SAFELY MAINTAIN MACROINVERTEBRATES OVERNIGHT?

1. Place rock packs of macroinvertebrates in a cooler with stream water from the source (the same site at which the animals were collected). Leave outdoors if cool (<15°C), keeping out of direct sunlight. Alternatively, store cooler indoors with freezer packs inside.
2. Use an insulated bucket (bait bucket) and add an air-stone. These items can be found inexpensively at local outdoor recreation / fishing stores or pet stores.
3. Store bags in a refrigerator.

Processing Rock Packs from the Stream (streamside or indoors)

MATERIALS

• Biotic Index Data Sheet (optional)	• Net-Spinning Caddisfly ID Guide	• white trays
• sieve (optional)	• spoons	• squirt bottle (optional)
• hand lenses	• brushes	• measuring cup
• petri dishes (optional)	• scissors	• sorting sheet (optional)
• identification keys	• buckets	• small trash bag for string

PROCEDURES PART I: PREPARING TO SORT ROCK PACKS

NOTES:

- You may simply identify ONLY net-spinning caddisflies, coming up with a total count per pack or across all packs. Alternatively, you may count and identify ALL macroinvertebrates, using the Biotic Index Data Sheet (Chapter 5) to determine a Pollution Tolerance Index score and rating (poor, fair, good, excellent).
- Streamside processing is preferable over indoor processing to minimize stress on the macroinvertebrates. If processing the packs indoors, keep the packs in a cooler with ice packs or in a refrigerator until they are processed.
- Prior to processing rock packs, it is highly recommended that teachers complete the Digital Detectives Activity (Chapter 3) with students and explore the macroinvertebrate identification resources found in Chapter 4.

1. Fill white trays with 1-inch of cool stream water (Collecting Rock Packs, Step 3). Teachers may opt to divide white trays among different student groups (e.g., students conducting an experiment on different grain sizes).
2. Untie or carefully cut open mesh bags and empty contents into the bucket of stream water. Be sure to look over the mesh bag, your hands, and clothes to remove macroinvertebrates that may still be hanging on!
3. Carefully remove rocks from the bucket(s), gently placing rocks in the white tray(s) of stream water. No worries if a macroinvertebrate has hitchhiked from a rock to the tray; we will be sorting through the trays soon!
4. Once all rocks are removed from the bucket(s), carefully pour contents of the bucket(s) (e.g., stream water with any macroinvertebrates or leaf litter) through a sieve into another bucket. Add second bucket of sieved content to tray(s) for sorting. ***NOTE:*** *This process is most easily done with 2-3 individuals. Additionally, it may be helpful to use a squirt/squeeze bottle to squirt water through the back of the sieve and into the white trays to dislodge more macroinvertebrates. Check the second bucket for any missed macroinvertebrates!*
5. Repeat Steps 3-4 for each rock pack. Make sure to keep rock packs separate and properly labeled so that the data you collect directly corresponds to each particular rock pack.

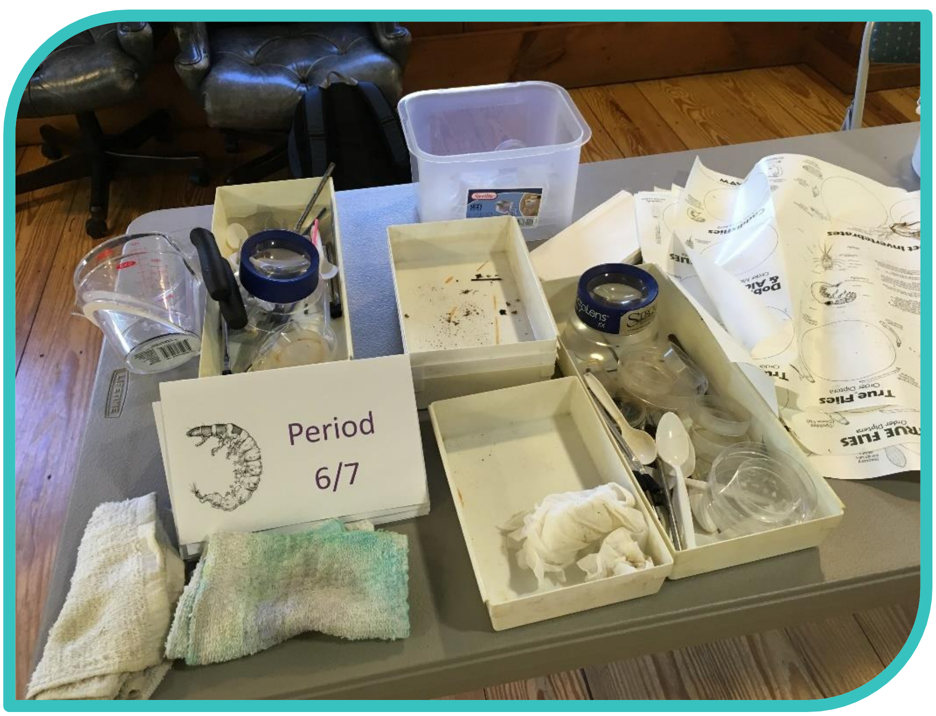
PROCEDURES PART II: SORTING ROCK PACKS AND SHARING YOUR DATA IN THE PORTAL

Optional: If identifying all macroinvertebrates (not only net-spinning caddisfly larvae) using the **Biotic Index Data Sheet**, it is useful to organize all individuals with the Leaf Pack Network sorting sheets (See Chapter 4 for purchase links). If using this, place a petri dish with stream water on each circle of the sorting sheet.

6. Using a clean paintbrush or plastic spoon (white recommended), place all macroinvertebrates that look alike in the same petri dish, sorting "like with like." Use hand lenses to check for the special characteristics of each macroinvertebrate. Use identification keys as needed.
7. Count the total number of individual net-spinning caddisfly larvae from all packs and record in the **Field Data Sheet**. Additionally, you can record all macroinvertebrate types on the optional **Biotic Index Data Sheet**, calculating the Pollution Tolerance Value and Rating as well as % Net-Spinning Caddisflies of the Total Macroinvertebrates recorded on the Field Data Sheet.
8. Data can be entered into the Monitor My Watershed data portal; go to www.wikiwatershed.org/help/leaf-pack-help for detailed instructions. Most data fields are mirrored in the database; if you only collected data on net-spinning caddisfly abundance (NOT on all macroinvertebrates), you may enter those specific data into the database.

PROCEDURES PART III: CLEAN-UP

9. Wash and dry all lab equipment before putting away.
10. Return macroinvertebrates alive to the section of stream they were collected from as soon as possible.
11. Any macroinvertebrates that die can be preserved for future educational uses in a reference collection if placed in 70% ethyl alcohol (can be purchased inexpensively from your local pharmacy).



CHAPTER 3: USING ROCK PACKS AS LEARNING TOOLS

This chapter provides guidance on using the Rock Pack Experiment to create authentic learning experiences focused on experimental design, experimental methods, and E-STEM skill-building, including advanced data collection and analysis, while connecting these experiences to state standards and curricular needs.

Importantly, the methods in the Rock Pack Experiment are very flexible and open to the type of design you would like to encourage in your students' experiments. The experiment is also a valuable extension of or alternative to the Leaf Pack Network, which can be used to establish baseline conditions and regular water-quality monitoring of a local waterway, as discussed in Chapter 1.

Rock Pack Goals and Learning Objectives

GOALS:

- To promote student inquiry by using scientific methods involving observational and explanatory activities
- To raise awareness of the importance of net-spinning caddisflies to stream ecosystems
- To use the Rock Pack Experiment and other educational resources to improve science education and teacher professional development

LEARNING OBJECTIVES:

At the conclusion of the Rock Pack Experiment, students will have:

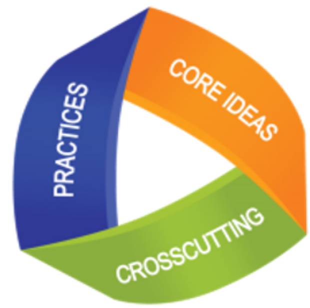
- ✓ Conducted a research-oriented investigation of their local streams
- ✓ Engaged in inquiry-based, hands-on data gathering and monitoring
- ✓ Observed and described freshwater aquatic food webs
- ✓ Identified net-spinning caddisflies
- ✓ Measured physical characteristics of a stream
- ✓ Drawn conclusions about the relationship between habitat, land-use and macroinvertebrate diversity and density
- ✓ Formulated research questions related to rock packs
- ✓ Analyzed macroinvertebrate data by using indices to assess water quality (optional extension)

Alignment with the Next Generation Science Standards

Teachers could potentially meet the following NGSS standards for grades 6-12:

Standards for 5, MS, and HS
LS2: Ecosystems: Interactions, Energy, Dynamics
LS4: Biological Evolution: Unity and Diversity
ESS3: Earth and Human Activity
ETS2: Engineering Design

Science and Engineering Practices
Asking Questions and Defining Problems
Planning and Carrying out Investigations
Analyzing and Interpreting Data
Developing and Using Models
Constructing Explanations and Designing Solutions
Engaging in Argument from Evidence
Using Mathematics and Computational Thinking
Obtaining, Evaluation, and Communicating Information



Disciplinary Core Ideas	Crosscutting Concepts
LS2.A: Interdependent Relationships in Ecosystems	Systems and Systems Models
LS2.C: Ecosystem Dynamics, Functioning, and Resilience	Cause and Effect
LS4.C: Adaptation	Stability and Change
ETS1.B: Developing Possible Solutions	Patterns
ETS1.A: Defining and Delimiting an Engineering Problem	
ETS1.C: Optimizing the Design Solution	
ESS3.C: Human Impacts on Earth Systems	

Getting Started with Students

Developing a plan of action can guide you in setting up and participating in the Rock Pack Experiment. It also helps you utilize the available resources to the fullest. You may choose to have students take part in all of the experiences or just participate in certain phases. Use some or all of the steps in the plan below as a guide to planning your project.

STEP 1: GENERAL INFORMATION

1. Which classes will participate in the Rock Pack Experiment?

2. How many students will participate? Which grades?

3. What stream will be used? What watershed or sub-watershed are we to study?

5. What logistical issues need to be addressed as you prepare to implement the Rock Pack experiment? (Include things like administrative, transportation, property access, schedules, collection permits, etc.)

6. How do you envision this project serving your curricular needs? Which topics will be of particular interest to you?

STEP 2: DESIGN THE EXPERIMENT

1. When do you plan to begin your project?

2. Describe the stream and location that the class will investigate. What conditions exist that will make this an interesting and effective location?

3. If experimental rock packs will be used, what will be investigated in the project? Your choice of variables might include:

ROCK SIZE! Either vary the average size (e.g., 10 millimeter b-axis diameter) or variation in sizes of rocks (e.g., some 10-mm rocks and 50-mm rocks together in one pack, or only 10-mm rocks in a pack) in the packs.

OR

WEIGHTS! Vary the weight of each rock pack (e.g., 200 grams vs. 1000 grams).

OR

LOCATION OF PACK! Place your packs in different areas of the stream (e.g. pool vs. riffle habitat, forest stream vs. meadow stream).

For example, student groups may form a hypotheses on the size of rocks/gravel net-spinning caddisflies will prefer during colonization. To measure this, student groups may prepare rock packs of varying sizes and later evaluate the density/number of net-spinning caddisflies per rock pack.

STEP 3: WORK PLAN & TIMELINE

Consider the following tasks while outlining a work plan or timeline. If time is a concern, it is not necessary to choose all of the components below.

I. Class Introduction to the Rock Pack Experiment, including stream ecology, aquatic macroinvertebrates, and net-spinning caddisfly larvae. TIP:use any of the videos found on the Rock Pack Experiment website!
II. Site Investigation
III. Preparing the Rock Packs for the Stream
IV. Placing the Rock Packs in the Stream
V. Collecting the Rock Packs From the Stream
VI. Processing the Rock Packs
VII. Sorting and Identification, with an emphasis on net-spinning caddisflies
VIII. Water Quality Calculations
IX. Sharing Data on the Leaf Pack Network Online Portal

CONSIDER THE FOLLOWING QUESTIONS:

1. How and when will you contribute your project data to the data portal?

2. How can your class use the web-based rock pack resources available at https://leafpacknetwork.org/?

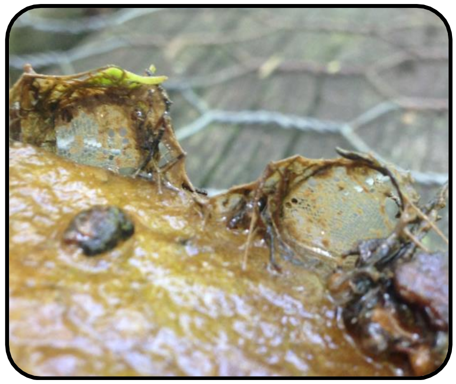
3. How will you engage students in communication of Rock Pack Experiment data through group discussion, presentations, and/or written assignments? NOTE: This may have important interdisciplinary connections to literacy, language arts, technology, engineering, physics, and more.

4. How else is information-sharing possible for the data your students generate? (e.g., conferences, school board meetings, township meeting, local conservation groups)

Optional Activities

The following pages include optional activities that serve as helpful extensions of E-STEM lessons as well as new opportunities to integrate other state standards or learning objectives, including physics and art.

Crafty as a Caddisfly: Build a Net!


The aquatic larvae of the net-spinning caddisfly (Order Trichoptera, Family Hydropsychidae) use silk threads woven into a mesh web to catch their dinner. As a **collector-gatherer** and **omnivore-detritivore** during at least part of its larval stage, these nets help the crafty critters use a feeding strategy called **filter-feeding** to capture small particles, such as broken-down leaves and other **detritus**, on their net's sticky threads.

There are many different caddisfly species, and individual species vary in the nets they create, including the number of silk threads in the net, the strength of the silk threads, and the size of the silk structure. The nets are created with great detail and precision, with each silk thread placed into just the right spot to create mesh webbing that will stretch and balloon with food. Now it's time to model net-building with your students to creatively introduce them to the world of the net-spinning caddisfly!

MATERIALS:

- Yarn or string (precut in 24-inch lengths by teacher)
- Visual aids on Pgs. 24-25 of net-spinning caddisfly larvae and silk webs/retreats (optional)
- WiFi and computer access to play *Caddisflies, Engineering an Ecosystem,* on vimeo (4 min, 33 seconds): https://vimeo.com/273597362

PREPARATION:

Cut yarn or string of different colors and strength into 24-inch lengths. Plan to conduct the activity with access to the outdoors so students can collect twigs. If outdoor access is not possible, pre-collect a bag of twigs of varying lengths, thickness, and species distributions. Twig identification is NOT necessary.

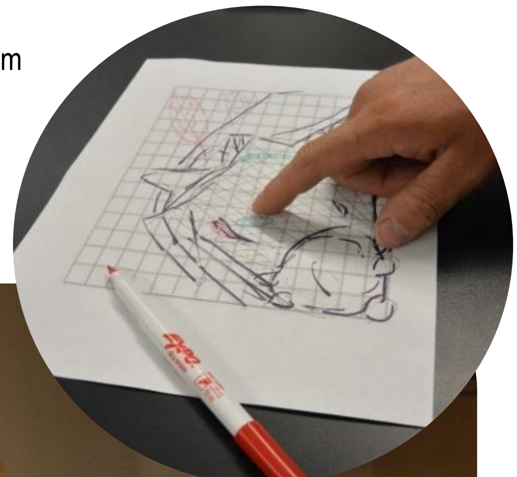
INSTRUCTIONS:

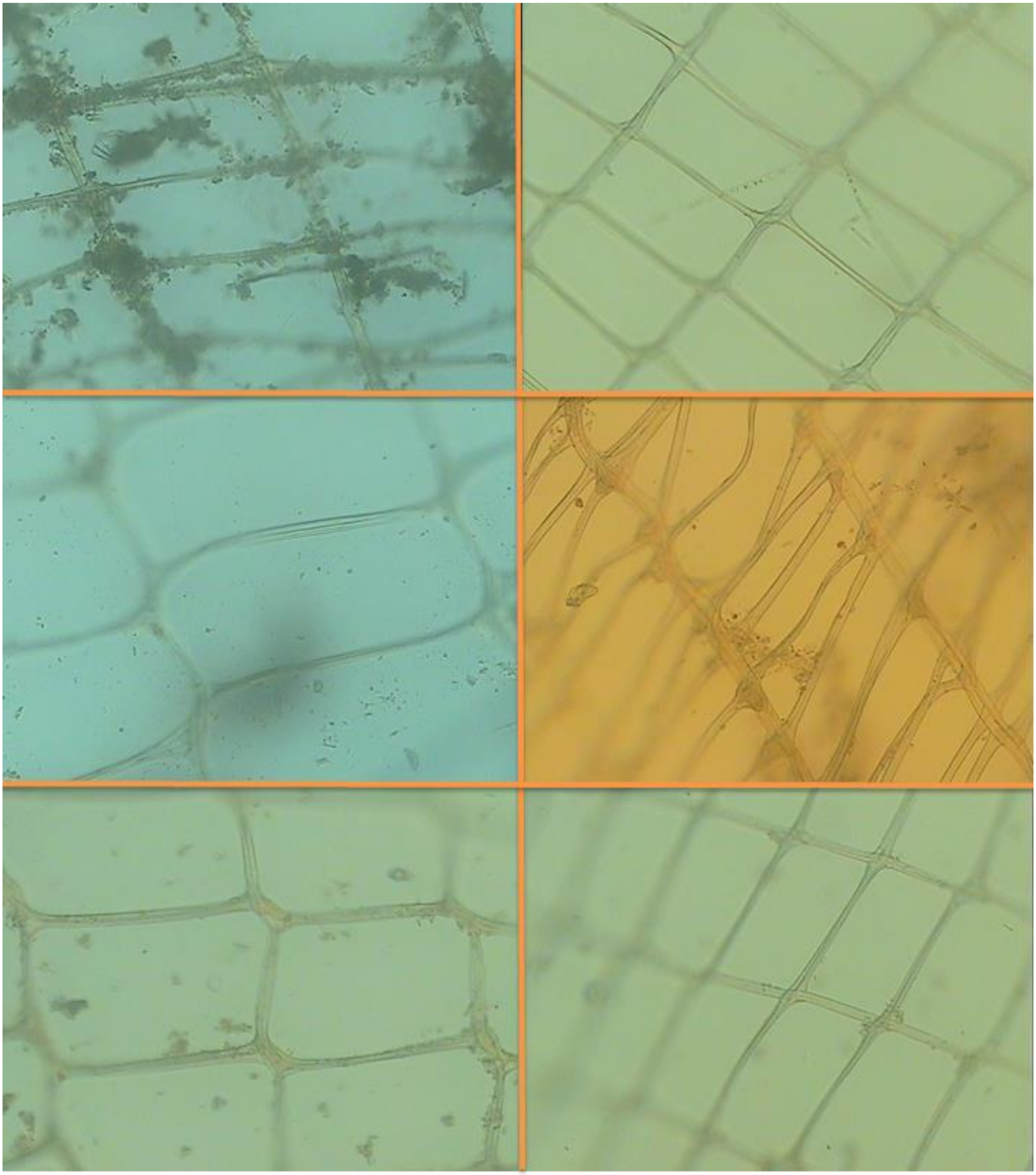
1. Each student collects twigs to serve as the frame for their net.
2. Using different colors and strengths of yarn, each student builds a net that they think resembles a caddisfly net.
3. Have the students present their nets and share why they chose their net's silk structure and design.

Continue to next three pages for activity extensions and visual aids!

CRAFTY AS A CADDISFLY EXTENSIONS:

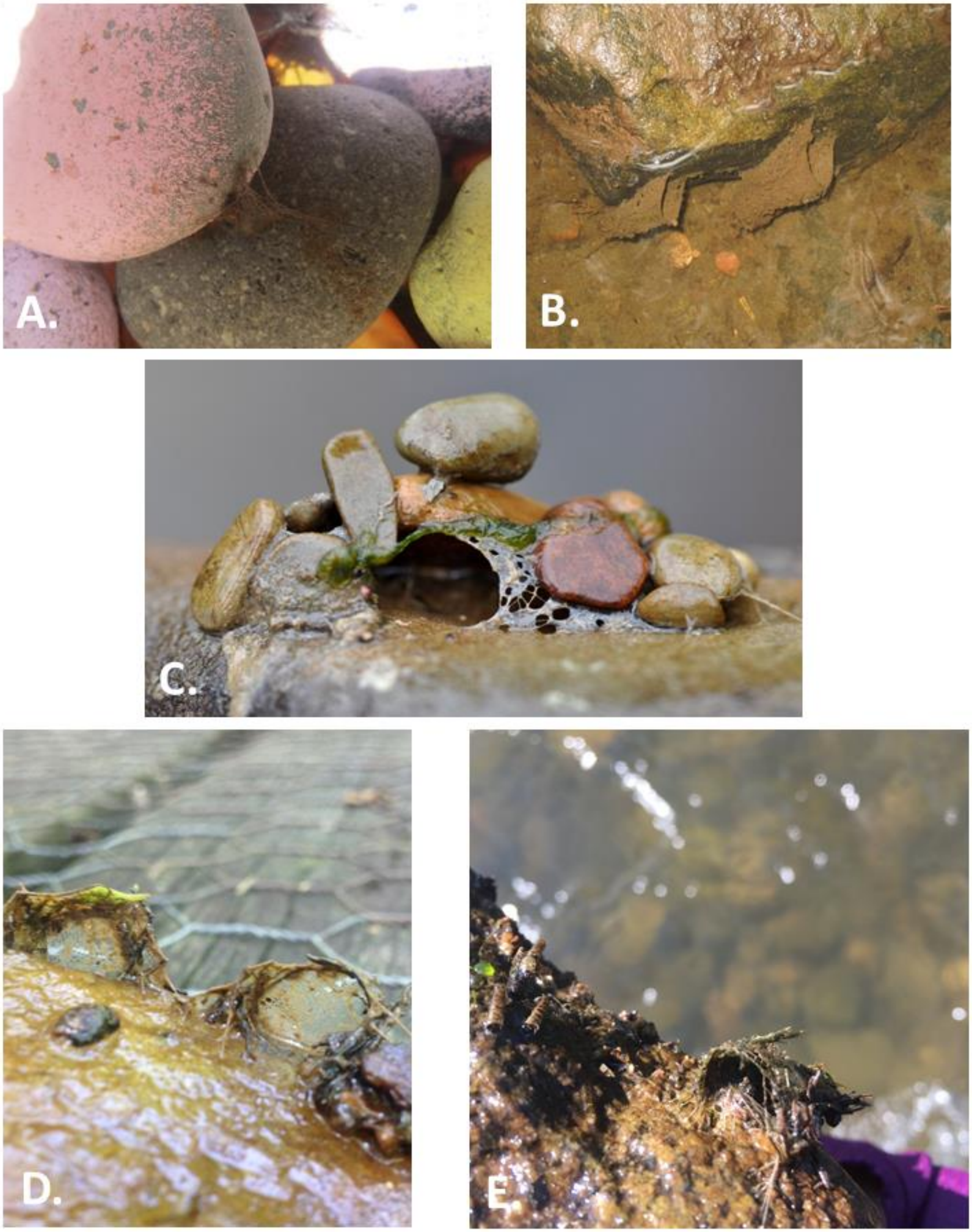
- **Simulate Energy Flow in a Stream!** If you have access to a stream or fan (or leaf blower!), consider having students make a much larger net, and then stand in the water or an open grassy area. Release handfuls of leaves upstream or in the wind, and see which student's net catches the most leaves.
  - Explain to students that leaves are the dominant source of carbon and energy for many streams, and provide habitat and food for aquatic macroinvertebrates like cranefly larvae, stonefly nymphs, and even crayfish. This "eating" process yields smaller particles (feces and leaf fragments), similar to "crumbs" created after eating crackers, for example), providing food for other highly specialized macroinvertebrates downstream. These small particles float downstream and catch on the sticky silk threads of net-spinning caddisfly webs. Bon appétit!
  - Throughout and following the activity, ask students: What might make their webs better at catching leaves (e.g., more threads, stronger threads, bigger webs, etc.)?
- **Graph It!** If you have older students, you can use graph paper to have them draw a structurally sound net. If you have access to AutoCad drawing software they can trace nets from pictures of caddisflies.





Caddisfly Silk Nets

Caddisfly Silk Retreats



Determining Stream Discharge

The amount of water moving past a point on the stream can be determined if four sources of data are known. The amount of water (cubic meters per second) is calculated using this formula:

channel width x water depth x roughness coefficient x water velocity = discharge (m^3/s)

MATERIALS:

tape measure	meter stick	clip board	pencil
boots	stop watch	floating device (walnut, orange, tennis ball)	

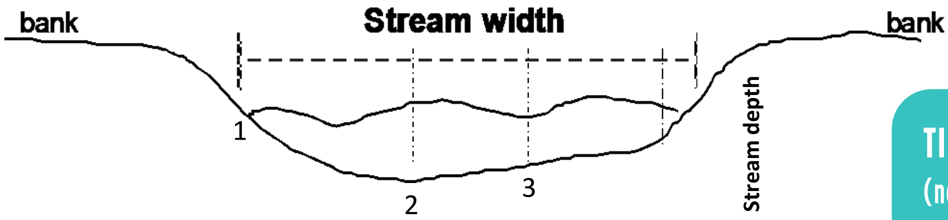
PROCEDURES:

Note: It is recommended that this exercise be completed before the rock packs are placed in the stream.

1) Stream channel width:

Step 1: In the proximity of the rock pack locations, stretch a tape measure tightly across the stream.

Step 2: Measure width from the water's edge, one bank to the other.



Stream width = _______m

TIP! If possible, select a straight stretch of stream (no bends), which will have unobstructed riffles and runs. Ideally, most of the 10 meters will be upstream of your packs.

2) Stream depth:

Step 1: Measure and record three equidistant depth measurements along the width transect.

________m ________m ________m

Step 2: Add all three measurements and divide the total by three to calculate the average.

Average stream depth = ________ m

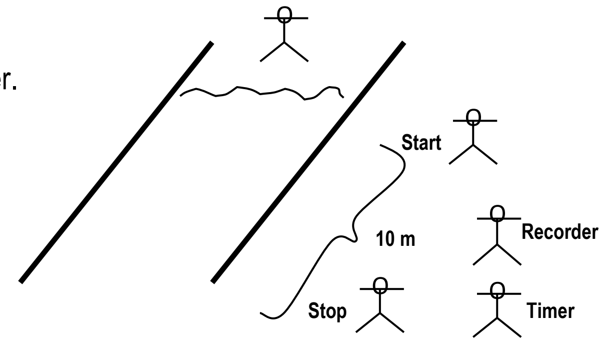
3) Velocity:

Step 1: Measure distance of 10 meters parallel to the stream, along or upstream of where you will place your rock packs.

Step 2: Place observers at the start and end of the 10-meter course, along with a person who is a recorder and a timekeeper.

Step 3: Float an object and record the time it takes to travel the 10 meters. Drop the float approximately 30 cm above the starting point.

Step 4: Observers are to call "start" and "stop" for the timekeeper. Timekeeper is to give readings to the recorder.



Step 5: Repeat this procedure three times. Add all three measurements and divide the total by three to calculate the average.

_________ sec   _______ sec   _______ sec

Average time: _________ sec

Step 6: To determine velocity, calculate: $\frac{\text{10 m (distance)}}{\text{average seconds}}$ =

Velocity = ______ m/sec

4) Calculating Volume of Flow/Discharge: How much water per second?

NOTE: Roughness Coefficient *is a value given for the type of stream bottom. Check the box that best describes the stream where you are working:*

- ☐ ***0.9*** *– if the stream bottom is smooth with silt, sand or bedrock*
- ☐ ***0.8*** *– if the stream bottom is rough with rubble, stones or gravel*

width x avg. depth x roughness coefficient x velocity = discharge (m^3/s)

_____ (m) x _____ (m) x _____ x _____ (m/s) = ______ (m^3/s)

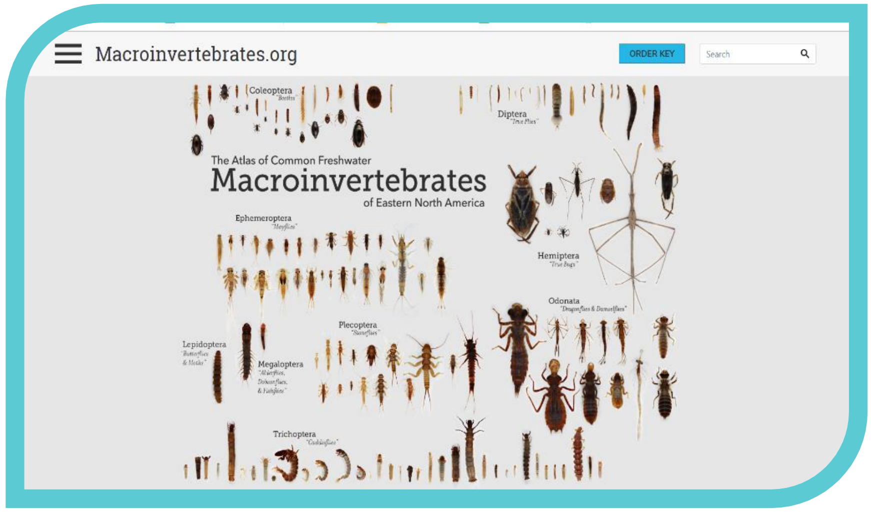
Discharge = ______ m^3/s

Conversion factor*: Multiply cubic meters/sec (m^3/s) by 35.31 to calculate cubic feet/sec (cfs).*

Digital Detectives: Caddisfly ID

This macroinvertebrate identification activity is highly recommended for an indoor setting *before* rock pack processing to orient students, teachers, trainers, and citizen scientists alike to net-spinning caddisfly identification. It also puts the "T" in E-STEM learning as participants use Macroinvertebrates.org, a dynamic, digital learning tool, this activity, to explore the identifying characteristics of the:

- Order level of caddisflies (Trichoptera)
- Family level of net-spinning caddisflies (Hydropsychidae)



The Macroinvertebrates.org online resource can be used to build confidence in identification of common freshwater macroinvertebrates across eastern North America.

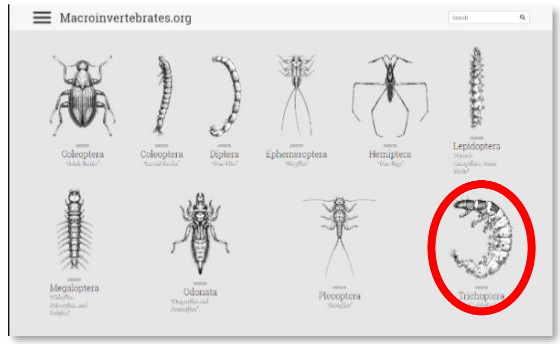
MATERIALS:

- ✓ WiFi Connection
- ✓ Computer(s), ideally one per individual or per small group
- ✓ Access to Macroinvertebrates.org
- ✓ Digital Detectives Activity: Instructional Slideshow (downloaded from https://leafpacknetwork.org/rock-pack/)
- ✓ Digital Detectives Activity: Net-Spinning Caddisfly ID Guide (downloaded from https://leafpacknetwork.org/rock-pack/)
- ✓ ID Focus Worksheet(s)
- ✓ Dichotomous Key (optional)
- ✓ ID Flashcards (optional)
- ✓ Live or preserved specimen with hand lenses (optional)
- ✓ STEM career highlight video of an entomologist from the Stroud Water Research Center: https://www.youtube.com/watch?v=S7ayyXPgkjU&list=PLrmuh958ChibSVPi6W1n8nGtis4nDw3Cp&index=1

PREPARATION:

- Participants should have a basic understanding of insect anatomy and aquatic macroinvertebrate life histories. You may want to first introduce what aquatic macroinvertebrates are as well as their general morphology. A next best step is also to have students become familiar with a dichotomous key which can be found here on the macroinvertebrates.org website: https://www.macroinvertebrates.org/key/

- The main activity is intended to be used in combination with the Instructional Slideshow and the Net-Spinning Caddisfly ID Guide to introduce the activity and basic insect anatomy, as well as the defining characters of the net-spinning caddisfly. These slideshows are available on the rock pack page of the Leaf Network website. The ID Guide may also be printed as a student worksheet, or completed as a large group as a PowerPoint projected onto a large screen.

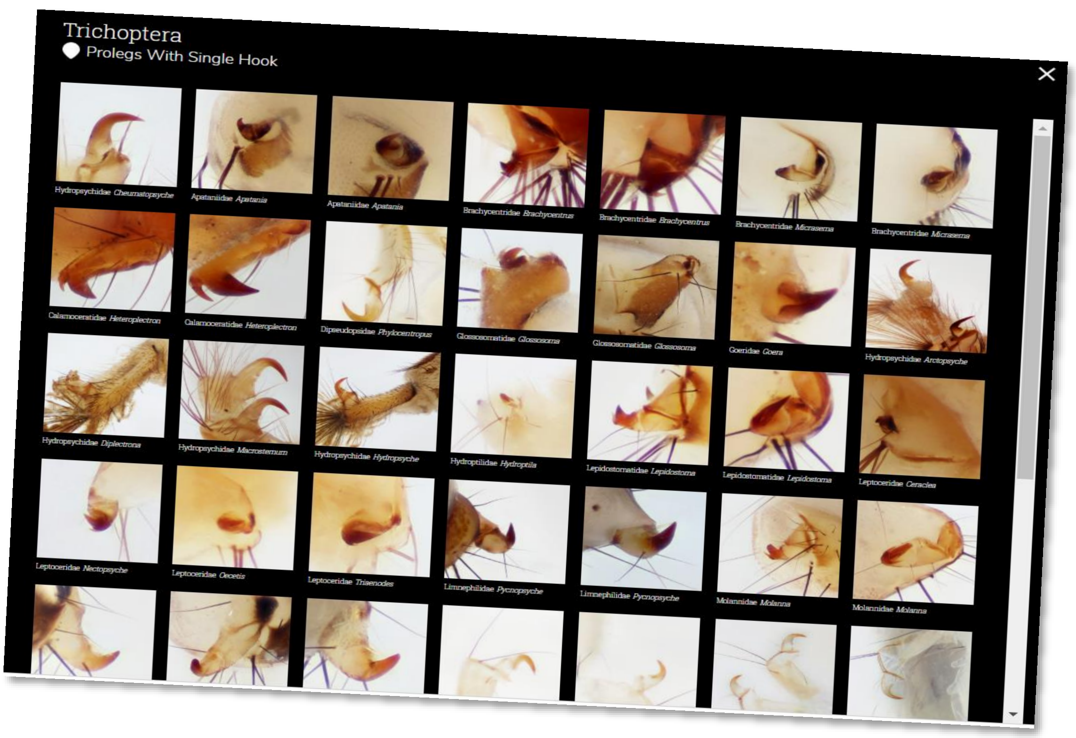


INSTRUCTIONS:

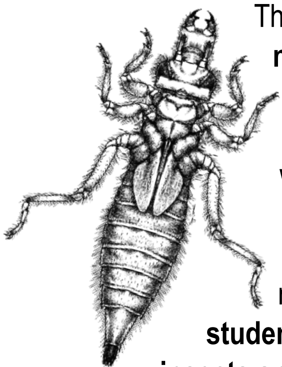
1. In small groups or as individuals, navigate to Macroinvertebrates.org. Select the order "Trichoptera," or the caddisflies, on the homepage from "The Atlas of Common Freshwater Macroinvertebrates." Alternatively, click the drop-down menu on the top left (three black lines), select "Navigational Views" from the menu, and select "Insect Order View." The order "Trichoptera" can then be selected.

2. Use the Net-Spinning Caddisfly ID Guide and the Instructional Slideshow in combination with Macroinvertebrates.org to explore the site and complete the ID Focus Worksheet.

3. Discuss your findings as a group. How does the dynamic imagery on the digital platform allow you to study the macroinvertebrates similar to entomologists in the laboratory? How can it build your confidence in hands-on identification with live specimens in the field? What new discoveries did you make about the defining characters of the net-spinning caddisfly?



Who Am I? Macroinvertebrate ID



This activity introduces students to the use of a dichotomous key to identify **benthic freshwater macroinvertebrates**, or “stream bugs” that inhabit the bottom/substrates (benthic) of streams, rivers, lakes, or ponds (freshwater), are big enough to see with the naked eye (macro, 0.2 – 0.5 mm), and lack a backbone/vertebrae (invertebrate). Macroinvertebrates play important roles in freshwater food webs and can also be valuable indicators of water quality.

Although these macroinvertebrates include animals like crayfish and mussels, many macroinvertebrates are aquatic insects that spend the first part or all of their lives underwater. **For students new to macroinvertebrates, it is recommended that this activity focuses only on the aquatic insects and their life cycles**, while integrating students’ existing understanding of insect anatomy (e.g., head, thorax, abdomen) and life cycles (e.g., the larval stage of a butterfly). Teachers may opt to extend the activity to include non-insect (e.g., crayfish, mussels, annelids, planarians) as students increase their understanding of macroinvertebrates.

MATERIALS:

- ✓ Macroinvertebrate ID flashcards (from the Leaf Pack Network Resources website page)
- ✓ Macroinvertebrate dichotomous key (see Macroinvertebrates.org OR the Resources section in Chapter 4)
- ✓ Clothespins

PREPARATION:

- Brainstorm names of familiar insects.
- Draw a generic insect body with help of participants. If age-appropriate, identify the insect anatomy together.
- Show caterpillar photo, asking if it is an insect. Using information and resources available in the Rock Pack Manual, discuss the unique life cycles and common larval stages of aquatic macroinvertebrates.
- Introduce the macroinvertebrate dichotomous key and how to use it.
- Generate a list of words regarding insect anatomy that are unfamiliar to the participants. Explain words to the students, showing images of aquatic macroinvertebrate anatomy.

INSTRUCTIONS:

1. Participants find a partner.
2. In student pairs, one individual selects a macroinvertebrate card and fastens it to the back of their partner without the partner seeing the card.
3. The individual with the card on their back holds the macroinvertebrate identification key in front of them and tries to figure out what macroinvertebrate they have by going through the key, s*trictly* asking questions that get a “Yes” or “No” response.
4. The individual answering the questions looks only at the macroinvertebrate photograph on the card for their response.
5. Once the individual with the key is *certain* of the macroinvertebrate fastened to their back, they can name the macroinvertebrate and discover whether they are correct by looking at the other side of the card.
6. Now, reverse roles and choose a new macroinvertebrate card!

Wentworth Pebble Count

From the *Georgia Adopt-A-Stream's Visual Stream Habitat Manual*

Identify the average gravel size in your stream! The Wentworth pebble count provides a method for quantitatively characterizing the substrate particles in your streambed by determining the percentage of silt, sand, gravel, cobbles, and boulders. The method requires a minimum of two people, but can also be done in larger groups. This method outlined below requires you to be in the stream. The accompanying data sheet can be found in Chapter 5.

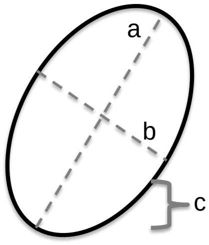
MATERIALS:

- ✓ Metric Ruler with a 2-mm mark Size Chart, calipers or
- ✓ Gravelometer (See below procedure for more info)
- ✓ Wentworth Pebble Grid
- ✓ Wentworth Pebble Count Data Sheet (Chapter 5)
- ✓ Pencil
- ✓ Clipboard

TIP! Before collecting rocks, weigh 100 grams of rocks of different sizes as a demonstration. This can help students understand how many rocks are required depending on the diameter of the rocks (e.g., more small rocks will be equal to fewer large rocks in total weight).

INSTRUCTIONS:

1. In teams of at least two people, select one team member to record data on the **Wentworth Pebble Count Data Sheet**. The remaining members of the group will be counters. You may wish to rotate these positions periodically throughout the pebble count. You may also wish to work in pairs of a counter and a note-taker.
2. Select a cross-section of your stream to sample. Look for an area of the stream with a representative number of **pools**, **riffles**, and/or **runs**. Make sure the area you choose is safe and wadeable.
3. Begin by wading through the stream (walking from downstream to upstream). Make sure to cover all areas of the stream cross-section up to the bankfull mark, the highest point water reaches on the banks before it spills into the floodplain. If only one person is counting, walk upstream in a zigzag from bankfull to bankfull. If a whole group is counting, walk upstream in a line formed from bankfull to bankfull.
4. When the recorder says "stop," each counter picks up the pebble closest to his/her right big toe. To avoid the natural tendency to pick up larger pebbles, you should pick a point on your toe or boot to use as a reference point. You should also use a reference point on the finger that descends into the water. The first particle touched by this point should be measured.
5. Using a ruler and the Size Chart, each counter determines if s/he has silt/clay, sand, gravel, cobble, boulder or bedrock. The pebble is measured at its middle length. This is not the longest or the shortest cross-section of the pebble, but in between.
6. Call the size out to be recorded on the data sheet.
7. Repeat the process until you have counted approximately 100 times.
8. Calculate the percentage that are silt/clay, sand, gravel, cobble, boulder or bedrock
9. Graph the number of pebbles versus pebble size.



Axis of a pebble

(a) Long axis
(b) Intermediate axis
(c) Short axis

APPROACHES TO MEASURING GRAVEL SIZE:

1. Use the Metric ruler, calipers or Wentworth grid to measure the length of the b-axis in centimeters (cm).
2. The following table contains particle size classes. Use the descriptions if you are making visual estimation. If more accurate measurements are taken, it is possible to obtain a clearer picture of changes in substrate composition over time.

Wentworth Pebble Count Size Chart

Size Class	Size Range (mm)	Description
Silt/Clay	< 0.062	Smooth when rubbed between fingers
Sand	0.062 – 2.0	May have some clay in it but you will feel the gritty texture.
Gravel	2.0 – 64.0	This line is just over 2 mm
Cobble	64.0 – 256.0	This line is about 64 mm. This page is just over 256 mm tall.
Boulder	256.0 – 4096.0	These are big.
Bedrock	N/A	Bare/exposed rock.

CHAPTER 4: REFERENCES & RESOURCES

Resources

Citizen science groups, teachers/students, and other participants in the Rock Pack Experiment should utilize as much or as little of the activities and data sheets in the Rock Pack Manual. These are designed as guidelines to enhance participant connections to local streams and macroinvertebrates, specifically the net-spinning caddisfly.

HELPFUL WEBSITES:

- The Leaf Pack Network®: https://leafpacknetwork.org/
- Macroinvertebrates.org: https://www.macroinvertebrates.org/
- WikiWatershed® Toolkit: https://wikiwatershed.org/
- Dichotomous Key on the Leaf Pack Network website: https://stroudcenter.org/macros/key/

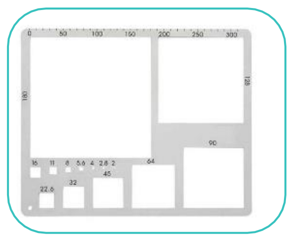
MATERIAL SOURCES:

- Leaf Pack Stream Ecology Kit (from the LaMotte Company): http://www.lamotte.com/en/education/macroinvertebrates/5882.html

- Luggage Scales: We like this one, as it has a hook for weighing the packs easily with the mesh bag and also has a measuring tape: https://www.youtube.com/watch?v=jCwD9d3UkWQ

- Calipers (digital, dial, or utility; Pittsburgh brand): https://www.harborfreight.com/search?q=calipers

- Gravelometer (Wildco brand): https://www.forestry-suppliers.com/product_pages/products.php?mi=22080&itemnum=53249&redir=Y



- Waterproof tags – 2 example options:
  - Rite in the Rain paper: https://www.riteintherain.com/?gclid=EAIaIQobChMIjtuh26j65wIVAobICh28ZgC6EAAYASAAEgJXg_D_B
  - Tyvek Wristbands (difficult to find among online retailers): Simply write on these with the waterproof marker.

Glossary

bioindicator organisms: plants or animals that tolerate only specific levels of pollution and are used to indicate water quality

bedload: gravels and cobbles that are rolled, hopped, pushed, and pulled along the streambed during large flow events; these rocks are too heavy for the water to actually lift up into the flow for more than a few seconds

benthic freshwater macroinvertebrates: an organism that inhabits bottom areas/substrates (benthic) of freshwater systems like lakes, ponds, streams, or rivers (freshwater), is large enough to be seen with the naked eye (macro), and does not have a backbone (invertebrate)

biodiversity: different kinds of specialized organisms in a particular habitat or ecosystem

caddisfly: highly advanced and diverse group of insects from the Order Trichoptera that live in fresh water for part of their life cycle; these insects spend their larva stage in water (aquatic) before undergoing complete metamorphosis into a winged adult that lives on land (terrestrial); renowned for their silk production

- **case-building caddisfly**: variety of families within the Order Trichoptera that use silk to craft portable, protective cases from small rocks and detritus
- **net-spinning caddisfly**: Family Hydropsychidae within the Order Trichoptera that uses silk to create 1) fixed retreats constructed from organic and inorganic materials, and 2) catch-nets to trap fine particles from the water column for food; globally distributed group and the most abundant caddisflies in many parts of North America

caddisfly silk: protein emitted from specialized silk glands at the tip of the labium (mouthpart) that functions like sticky, stretchy, waterproof tape for the complex creation of cases, retreats, nets, and cocoons

complete metamorphosis: the process of completing a four-stage life cycle consisting of an egg, larva, pupa, and adult stage; examples of insects that undergo complete metamorphosis include caddisflies, true flies, beetles, and dobsonflies

dissolved oxygen: the amount of oxygen that is present in water and available to living organisms to use for respiration

ecology: the scientific study of the abundance, distribution, and interaction of organisms (plants and animals) on the earth

ecosystem: a community of interacting organisms and their physical environment

ecosystem engineers: animals or plants that maintain, modify, or create habitats

erosion: process of sediments being broken down by natural agents like water and wind

filtering collectors: organisms that feed by collecting and filtering small particles of organic matter, sometimes referred to as fine particulate organic matter (FPOM), found in the water column and bottom substrate of a stream; these specialized feeders include net-spinning caddisfly larvae

fluvial geomorphology: the scientific study of the physical shape of rivers and the processes that change them over time;

> **fluvial** (processes associated with running water) **+**
> **geomorphology** (processes that shape the Earth's surface)

functional feeding groups: method of classifying macroinvertebrates based on feeding adaptations and/or preferences

habitat: food, water, shelter, space; the natural home or environment of an animal, plant, or other organism

incomplete metamorphosis: the process of completing a three-stage life cycle consisting of an egg, nymph, and adult stage; examples of insects that undergo incomplete metamorphosis include mayflies, dragonflies, damselflies, stoneflies, and true bugs

leaf packs: naturally forming accumulation of leaves within a stream that provide habitat and food for aquatic organisms; can also be artificially created as mesh bags filled with leaves, grass, or other vegetation to simulate natural leaf packs

macroinvertebrates: an organism that does not have a backbone and can be seen with the naked eye

retreat: crude dwelling constructed by net-spinning caddisfly larvae from organic and inorganic materials (e.g., small rocks, detritus, leaf fragments) bound together by silk protein and adhered to rock surfaces or woody debris in the stream; utilized as habitat

riffle: the shallow area of a stream through which water moves swiftly and there are many rocks

rock packs: dry rocks in mesh bags that simulate the naturally available rock habitat found in a stream

species composition: the identity of all the different organisms that make up an ecological community

watershed: a land area bounded by a divide and draining to a particular body of water or watercourse

water quality: the overall health of a body of water, including the measured chemical, physical, and biological characteristics

References

NOTE: Some references are published in open-access journals and hyperlinks are below to access online the free pdf!

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Life in Freshwater.net

CHAPTER 5: DATA SHEETS

This chapter includes both printable blank data sheets and example data sheets for the following:

- Biotic Index Data Sheet
- Rock Pack Field Data Sheet*
- Site Map Data Sheet*
- Wentworth Pebble Count Data Sheet

Data sheets with an asterisk* are strongly recommended for a successful Rock Pack Experiment. All other data sheets are optional extensions.

BIOTIC INDEX DATA SHEET

1

Group 1: Sensitive	Group 2: Somewhat Sensitive	Group 3: Tolerant
☐ Stoneflies	☐ Damselflies	☐ Midge Flies
☐ Mayflies	☐ Dragonflies	☐ Black Flies
☐ Other Caddisflies	☐ Sowbugs	☐ Planarians
☐ Dobsonflies, Fishflies, and Alderflies	☐ Scuds	☐ Leeches
☐ Riffle Beetle Larvae/ Adults	☐ Crane Flies	☐ Left-Handed Snails
☐ Water Pennies	☐ Clams/Mussels	☐ Aquatic Worms
☐ Right-Handed Snails	☐ Crayfish	☐ Rat-Tailed Maggots
☐ Aquatic Snipe Flies	☐ Net-Spinning Caddisflies	
3 ☐ Number of TAXA	☐ Number of TAXA	☐ Number of TAXA

4 *Number of TAXA x 3 = INDEX VALUE* ☐ *Number of TAXA x 2 = INDEX VALUE* ☐ *Number of TAXA x 1 = INDEX VALUE* ☐

Date: __________

Investigator Names: __________

Time: __________ AM/PM

Leaf Pack Location: __________

2 ☐ **Sum of All Individuals**

[Add the values from all boxes next to the taxa names]

5 ☐ **Pollution Tolerance Index (PTI) Score**

[Add the three Index Values]

6 **POLLUTION TOLERANCE INDEX RATING**

23 or more	**Excellent**	☐
17-22	**Good**	☐
11-16	**Fair**	☐
10 or less	**Poor**	☐

Calculating the Biotic Index

Sort the macroinvertebrates into taxa groups.

1. Count the number of individual macroinvertebrates for each taxa. Record the quantity in the box to the left of the taxa name.
2. Determine the **Sum of All Individuals** by adding the numbers in the boxes next to all of the the taxa names. Record the total in the **Sum of All Individuals** box on the far right.
3. Count how many boxes in each sensitivity group column have a quantity entered. (Group 1 and Group 2: maximum 8, Group 3: maximum 7). Enter the **Number of TAXA** in the box at the bottom of each column.
4. Multiply the **Number of TAXA** by the weighting factor (3, 2 or 1) at the bottom of the column to obtain the **Index Value** for each Sensitivity Group.
5. Add the **Index Values** for the three groups to determine the **Pollution Tolerance Index (PTI) Score**. Enter the **PTI Score** in the box.
6. Determine the **Pollution Tolerance Index Rating** from the PTI Score.

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BIOTIC INDEX DATA SHEET

1

Group 1: Sensitive		Group 2: Somewhat Sensitive		Group 3: Tolerant	
55	Stoneflies	0	Damselflies	13	Midge Flies
30	Mayflies	5	Dragonflies	5	Black Flies
16	Other Caddisflies	3	Sowbugs	8	Planarians
0	Dobsonflies, Fishflies, and Alderflies	0	Scuds	0	Leeches
4	Riffle Beetle Larvae/ Adults	3	Crane Flies	0	Left-Handed Snails
6	Water Pennies	1	Clams/Mussels	1	Aquatic Worms
10	Right-Handed Snails	0	Crayfish	0	Rat-Tailed Maggots
2	Aquatic Snipe Flies	22	Net-Spinning Caddisflies		
3 7	Number of TAXA	5	Number of TAXA	4	Number of TAXA

4 *Number of TAXA x 3 = INDEX VALUE* 21 *Number of TAXA x 2 = INDEX VALUE* 10 *Number of TAXA x 1 = INDEX VALUE* 4

Date: 04/22/2019

Investigator Names: Vince O., Tara M.

Time: 11:00 AM/PM

Leaf Pack Location: White Clay Creek above Spencer Rd

2 184 **Sum of All Individuals**

[Add the values from all boxes next to the taxa names]

5 35 **Pollution Tolerance Index (PTI) Score**

[Add the three Index Values]

6 **POLLUTION TOLERANCE INDEX RATING**

23 or more	**Excellent**	✓
17-22	**Good**	
11-16	**Fair**	
10 or less	**Poor**	

Calculating the Biotic Index
Sort the macroinvertebrates into taxa groups.

1. Count the number of individual macroinvertebrates for each taxa. Record the quantity in the box to the left of the taxa name.
2. Determine the **Sum of All Individuals** by adding the numbers in the boxes next to all of the the taxa names. Record the total in the **Sum of All Individuals** box on the far right.
3. Count how many boxes in each sensitivity group column have a quantity entered. (Group 1 and Group 2: maximum 8, Group 3: maximum 7). Enter the **Number of TAXA** in the box at the bottom of each column.
4. Multiply the **Number of TAXA** by the weighting factor (3, 2 or 1) at the bottom of the column to obtain the **Index Value** for each Sensitivity Group.
5. Add the **Index Values** for the three groups to determine the **Pollution Tolerance Index (PTI) Score**. Enter the **PTI Score** in the box.
6. Determine the **Pollution Tolerance Index Rating** from the PTI Score.

STROUD WATER RESEARCH CENTER   Leaf Pack Network   LaMotte

Drawing Credits:
All drawings are from Stroud Water Research Center

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Rock Pack Field Data Sheet 

SITE INFORMATION

Organization/Group Name: ____

Investigators: ____

Site Code: ______________________ Site Name: ______________________

Stream Name: ______________________ Total Time Spent Monitoring: ____________ HH:MM

Major Watershed: ______________________ Number of Participants: ______________________

Sub-Watershed: ______________________ Latitude: ______________________

Closest town/city: ______________________ Longitude: ______________________

PACK DATA

Placement Data		Retrieval Data	
Date (Month/Day/Year)		Date (Month/Day/Year)	
Number of Packs		Number of Packs	
Air Temp (°C)		Air Temp (°C)	
Water Temp (°C)		Water Temp (°C)	

Avg. Weight of Packs: __________ grams

Habitat type for placement: Pool ☐ Riffle ☐ Run ☐

STORM & NON-STORM EVENTS

A. Did any storm events occur while your rock packs were in the stream?

Unknown ☐
Yes ☐
No ☐

If 'Yes' for A, list the following:

Storm Date	Precipitation (cm)
Total Amount (cm)	

B. Did flooding occur?

Unknown ☐
Yes ☐
No ☐

C. Was this site experiencing a drought during your monitoring?

Unknown ☐
Yes ☐
No ☐

BIOTIC DATA

From ALL Packs, # of Net-spinning Caddisflies (Order Trichoptera, Family Hydropsychidae): ______

From ALL Packs, # of Total Macroinvertebrates (including Hydropsychidae): ______

Optional Data from the Leaf Pack Network® Biotic Index Data Sheet:

Pollution Tolerance Index (PTI) Score: ______

PTI Index Rating: Excellent ☐ Good ☐ Fair ☐ Poor ☐

Please submit data to our online portal at MonitorMyWatershed.org

EXAMPLE: Rock Pack Field Data Sheet

SITE INFORMATION

Organization/Group Name: White Clay Creek Club

Investigators: Vince O., Mandy N., Steve K., and Tara M.

Site Code: WCC-US1

Site Name: White Clay Creek above Spencer Rd

Stream Name: White Clay Creek

Total Time Spent Monitoring: 3: 15 HH:MM

Major Watershed: Delaware

Number of Participants: ______

Sub-Watershed: Brandywine-Christina

Latitude: 39.85914

Closest town/city: Avondale

Longitude: -75.78369

PACK DATA

Placement Data		Retrieval Data	
Date (Month/Day/Year)	04/01/2020	Date (Month/Day/Year)	04/22/2020
Number of Packs	4	Number of Packs	3
Air Temp (°C)	15.5	Air Temp (°C)	16.0
Water Temp (°C)	12.0	Water Temp (°C)	12.3

Avg. Weight of Packs: 750 grams

Habitat type for placement: Pool ☐ Riffle ☑ Run ☐

STORM & NON-STORM EVENTS

A. Did any storm events occur while your rock packs were in the stream?

Unknown ☐
Yes ☑
No ☐

If 'Yes' for A, list the following:

Storm Date	Precipitation (cm)
04/17/2020	6 cm
Total Amount (cm)	6 cm

B. Did flooding occur?

Unknown ☐
Yes ☐
No ☑

C. Was this site experiencing a drought during your monitoring?

Unknown ☐
Yes ☐
No ☑

BIOTIC DATA

From ALL Packs, # of Net-spinning Caddisflies (Order Trichoptera, Family Hydropsychidae): 22

From ALL Packs, # of Total Macroinvertebrates (including Hydropsychidae): 184

Optional Data from the Leaf Pack Network® Biotic Index Data Sheet:

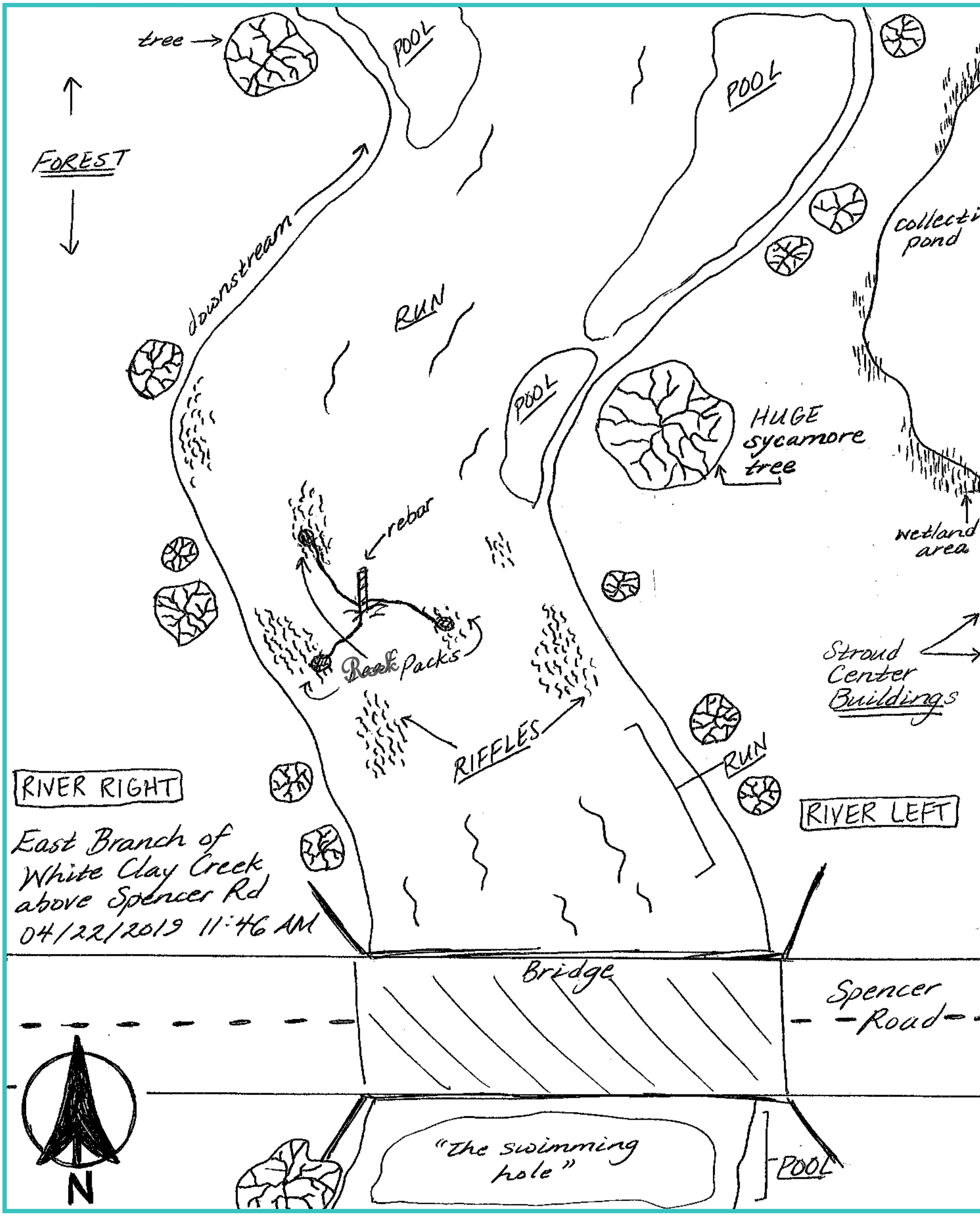
Pollution Tolerance Index (PTI) Score: 35

PTI Index Rating: Excellent ☑ Good ☐ Fair ☐ Poor ☐

Please submit data to our online portal at MonitorMyWatershed.org

Rock Pack Site Map

EXAMPLE: Rock Pack Site Map



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Wentworth Pebble Count Data Sheet

Use this data sheet to quantitatively characterize the substrate particles in your streambed, including silt, sand, gravel, cobbles, and boulders. For instructions, please see the Wentworth Pebble Count Activity in Chapter 3.

COUNT	SIZE (mm)	COUNT	SIZE (mm)	COUNT	SIZE (mm)
1		39		77	
2		40		78	
3		41		79	
4		42		80	
5		43		81	
6		44		82	
7		45		83	
8		46		84	
9		47		85	
10		48		86	
11		49		87	
12		50		88	
13		51		89	
14		52		90	
15		53		91	
16		54		92	
17		55		93	
18		56		94	
19		57		95	
20		58		96	
21		59		97	
22		60		98	
23		61		99	
24		62		100	
25		63			
26		64			
27		65			
28		66			
29		67			
30		68			
31		69			
32		70			
33		71			
34		72			
35		73			
36		74			
37		75			
38		76			
Average gravel size is: __________(mm)					
TOTAL % GRAVEL within 10mm-60mm range is: __________(%)					

EXAMPLE: Wentworth Pebble Count Data Sheet

COUNT	SIZE (mm)	COUNT	SIZE (mm)	COUNT	SIZE (mm)
1	8	39	68	77	1
2	22	40	52	78	8
3	15	41	360	79	6
4	13	42	210	80	36
5	50	43	112	81	22
6	65	44	22	82	220
7	100	45	6	83	1
8	92	46	14	84	8
9	45	47	140	85	1
10	15	48	8	86	13
11	13	49	51	87	52
12	24	50	44	88	15
13	8	51	26	89	68
14	68	52	8	90	1
15	300	53	78	91	1
16	26	54	70	92	6
17	70	55	36	93	22
18	36	56	8	94	8
19	15	57	100	95	2
20	1	58	178	96	8
21	100	59	15	97	54
22	8	60	222	98	26
23	13	61	68	99	44
24	1	62	99	100	8
25	22	63	22		
26	68	64	60		
27	8	65	140		
28	8	66	8		
29	1	67	8		
30	1	68	76		
31	47	69	58		
32	12	70	32		
33	22	71	12		
34	52	72	8		
35	46	73	14		
36	8	74	13		
37	22	75	144		
38	13	76	68		

Average gravel size is: 47.27 (mm) (mm)

TOTAL % GRAVEL within 10mm-60mm range is: 74 (%)