Benthic Macroinvertebrate Sampling and Freshwater Quality Monitoring

McMurray Middle School, Vashon Island
Scientists in Schools

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We drink rain. Rain feeds our streams, ponds and becomes our groundwater. Island water sources are not replenished by off-island snow melt or aquifers. What falls from the sky or discharges from our homes and businesses, is what we depend on to support our way of life, the quality of the water we drink, and the fish and wildlife that share our Island. (Source: Assessing Our Liquid Assets, Protection Committee, 2010)

Vashon Nature Center

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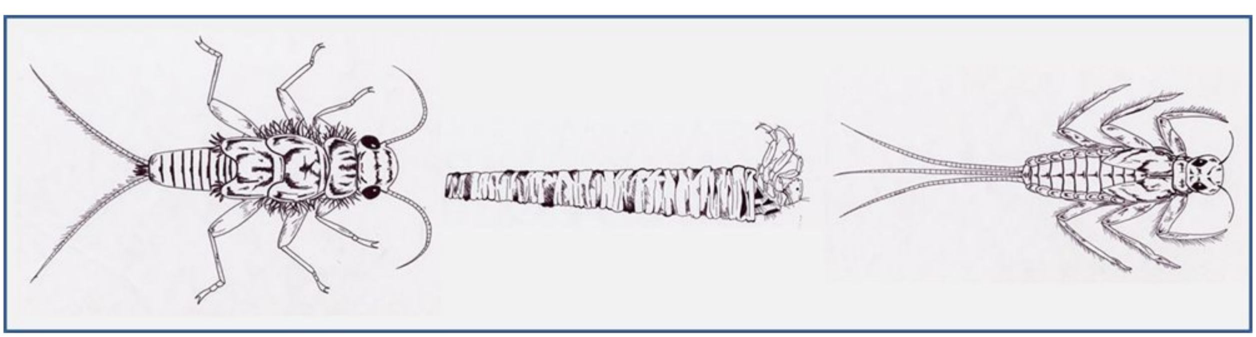


Unit Goals and Objectives

Goals:

- Demonstrate potential career opportunities in science.
- Facilitate research with community-based implications.
- Teach the applied methods of scientific research.
- Inspire participation in citizen science and its ability to create positive change.
- Explore what scientists do, how to conduct research, and the process of collaborative work.

Objectives:
Students will

- Participate in methods of field biology as it relates to macroinvertebrates, freshwater quality, and watershed health.
- Translate the results of their work to provide feedback to local land managers and community members.
- Engage directly in the sampling, sorting, and analyzing of data.
- Receive feedback on previous successes and opportunities for further engagement.
- Support their claim, evidence, reasoning argument both independently, and collaboratively in a small group.

Structure

Unit Introduction - In Class (50-minutes)
Field Sampling - In Field (75 minutes)
Lab Introduction - In Class (50-minutes)
Sorting Lab - In Class (50 minutes)
C-E-R Introduction - In Class (50 minutes)
Data Analysis and Research - In Class (multiple 50 minute periods)
Present Analysis and Research - In Class (multiple 50 minute periods)

Composition

This unit is composed of the introduction and six additional parts to be taught over nine class periods (or more as time allows). It includes an extension option.

1. Unit Introduction
   ~ Show a short film to excite students about benthic macroinvertebrates
   ~ Introduce the concepts of watersheds, riparian areas, and water quality monitoring
   ~ Students examine and compare mock stream conditions
   ~ Students complete an independant C-E-R to defend their statement of stream health
2. Field Sampling
   ~ Students look at the physical characteristics of the stream
   ~ Students sample freshwater benthic macroinvertebrates
   ~ Students play Macroinvertebrate Mayhem game (a game of tag simulating the effects of environmental stressors on macroinvertebrates; instructions in appendices)
3. Lab Introduction
   ~ Introduce taxonomic structure and
   ~ Introduce Macroinvertebrate Orders focused on in this unit
   ~ Students will perform a group pop quiz to test their identification skills
4. Sorting Lab
   ~ Students work in groups to sort the macroinvertebrates to taxonomic Order.
5. Sample Analysis
   ~ Students work in small groups to make a **claim** regarding the health status of the creek. The data collected will be used as **evidence** to support the claim. And students will provide **reasoning** to explain how the evidence supports the claim.
6. Posters
   ~ Students work in small groups to create posters to illustrate their analysis.
7. Presentations
   ~ As a group, students will present their research to the class.

Extension Option:

~ Classes can peer select a single group of students to present their work to a larger audience such as a Groundwater Protection Committee meeting, Vashon Nature Centers Ed Talks, the Earth day Celebration, or any other venue which seems appropriate.

Table of Contents

I - Unit Introduction (50 minutes)

Goals:

- Develop the concept of watershed boundaries.
- Demonstrate the ability to determine stream health from biological sample analysis.
- Understand the unit flow as a whole and what is expected by the end.

Objectives:

- Using wall maps, students will identify the watershed in which they live or attend school.
- Comparing various examples of mock streams, students will make claims regarding stream health.
- View posters created by students from past years, allowing them to see how we will analyze and present the data we collect.

Materials:

1. Powerpoint presentation for introduction (1)
2. Large “Vashon Maury Island” map delineating watershed boundaries (1)
3. Sticky notes, small (1 per student)
4. Stream sampling nets (2)
5. Laminated macroinvertebrate cards (1 set; see appendix)
6. PBS Digital Studios Deep Look Series on caddisflies (see appendix)
7. YouTube short film about French artist Hubert Duprat who uses caddisflies in his art.

I - Unit Introduction, Background Information

Since 2013, McMurray Middle school 6th grade students have been assisting Vashon Nature Center scientists in monitoring the water quality of island freshwater creeks. The object of this monitoring is to measure the health of the creeks. This is done by gathering information on the **physical**, **chemical**, and **biological characteristics** of each individual creek.

Physical characteristics include:

1. Riparian plants
2. Wetted width (width of the water in the creek bed)
3. Substrate size (the size of the stones, gravel, or sand on the bottom of the creek)
4. Amount of large woody debris (fallen wood)
5. The ratio of pools (where water slows) and riffles (where water runs fast)

Chemical characteristics include:

1. Temperature
2. pH (a measure of the acidity of water)
3. Dissolved oxygen (a measurement of the oxygen available to aquatic organisms)

Biological characteristics are measured by the individuals present in the benthic macroinvertebrate population. Benthic means bottom-dwelling—macroinvertebrates that live in and on the substrates of the stream (rather than in the flowing water or in the hyporheic zone).

Stream health can convey information about the health of the entire **watershed**. A watershed is an area of land from which sediment, water, and dissolved materials drain to a common water course or body of water. They are like funnels or basins. Watersheds can be many different sizes. Vashon Maury Island is about 37-square miles in size with about 75 drainage basins. Each drainage basin is its own watershed. Multiple small watersheds (sub-watersheds) can be grouped together to form a larger watershed. Watershed characteristics are influenced by climate, size, soil type, vegetation, and human activity.

Riparian areas are the interface between a stream or river and the land. The word ‘riparian’ derives from the Latin word ‘ripa,’ which means bank. A riparian area includes the creek and adjacent lands that have specific plant communities and soil types.

Studying riparian areas provides an idea of the health of the entire watershed it drains, not just the health of the creek itself. Thus, gathering this data provides us with a picture of watershed health. Physical and chemical characteristics only provide a snapshot of the creek through time. Because living organisms reside in streams for long periods of time, these biological components of a stream reflect its health spanning years not weeks or hours, as with the physical and chemical characteristics that can change quickly and vary widely.

Benthic Macroinvertebrates can be classified by:

1. Tolerance (to a suite of environmental stressors like temperature, sediment, oxygen, pollutants):
   Intolerant or tolerant
2. Feeding function:
   Shredders
   Gatherers/collectors
   Filter feeders
   Scrapers
   Predators
3. Behavior:
   Clingers
   Swimmers
   Burrowers
   Sprawlers
   Climbers
4. Habitat:
   Open river/stream
   Flowing water
   Still water
   Rocks
   Stream edge
   Pool
   Plant matter (ie. mosses or leaf litter)
5. Taxonomy:
   All life on earth is organized by a taxonomic classification system that categorizes life based off of shared traits. Classifications move from large, general groups (like plants) to smaller and more closely related groups (like bananas). The system is arranged as follows: Kingdom - Phylum - Class - Order - Family - Genus - Species. One simple mnemonic to recall the taxonomic levels is:
   king - philip - crossed - oceans - for - good - spaghetti

   This unit focuses on identifying biological samples of macroinvertebrates to taxonomic Order (and continuing to Genus and Species when possible). The Taxonomic Orders focused on in this unit are:

Plecoptera (Stoneflies); Ephemeroptera (Mayflies); Tricoptera (Caddisflies); Diptera (True flies); and Others (aquatic organisms such as beetles and dragonfly larvae).

What is a benthic macroinvertebrate? Macroinvertebrates are:

- The immature phase (larvae and nymphs) of flying insects, which often look VERY different from their adult flying form and spend this entire cycle of their life under water.
- A vital food source for juvenile salmonids, other freshwater fish, birds, and other invertebrates.
- Wide ranging in their ability to tolerate poor water quality.
- Some are long-lived, which makes them excellent indicators of the long-term picture of stream health (especially compared to physical and chemical characteristics which can change quickly and vary widely).
- Essential in the decomposition of organic matter in the stream.
- Critical to the overall complexity of an ecosystem.

Benthic macroinvertebrates are collected (sampled) from the streams using methods as illustrated in this WA Dept. of Ecology Video.
Link: https://www.youtube.com/watch?v=IuNn4VqFtJI

In the Puget Sound region, all data collected from monitoring freshwater stream health is stored at the Puget Sound Benthos website.
Link: https://www.youtube.com/watch?v=IuNn4VqFtJI

Data is scored using a system called the **Benthic Index of Biotic Integrity (B-IBI).** The B-IBI was created by a fish biologist at the University of Washington named James Karr. His expertise was not invertebrates, it was fish. He used observation and reasoning skills to create this index that is now a standard across the world for measuring stream health.

I - Unit Introduction, Teaching Methods

1. Show the [Deep Look - Caddisfly] video to hook the students' attention.
   Link:
   https://www.youtube.com/watch?annotation_id=annotation_2631367953&feature=iv&src_vid=svpP4HdsNI8&v=Z3BHrzDHoYo

   Caddisflies are a freshwater benthic macroinvertebrate. We will study macroinvertebrates and how they help us determine stream health in this unit.

2. Explain the concept of watersheds.

Activity: Using a large wall map of island watersheds, point out the location of the school and the watershed it is located in. Have students label the map with different places—their homes, school, town, parks, etc.

3. Discuss riparian areas and the characteristics that define them.

Activity: Set up two mock stream stations in the classroom. In one stream place a diverse assemblage including intolerant organisms and a few tolerant organisms. Make the overall abundance high. In the other stream, place a less diverse assemblage, including more tolerant organisms, less intolerant organisms and lower overall abundance.

Students make a determination about which steam might be healthier based on what they observe.

Students cue into their ability to observe, see patterns, and make educated guesses regarding steam health just using their observation skills. For example, even though they know nothing about the insects, they can look at the total counts of insects in each stream and see that one stream has more and that it also has more variety in types of creatures. They can then think about what that quantifiable difference might mean in terms of stream health.

Making these kinds of connections are essential to helping students to think like scientists.

4. Briefly discuss the results from the mock stream analysis.

Activity: Students complete a C-E-R worksheet (a baseline to compare with the final C-E-R students will complete AFTER sorting the actual samples).

5. Inform students of the expectations on the field trip. Advise towards weather-appropriate clothing. Suggest students pack a change of clothing or extra socks to keep in their locker at school on the day of in case of any mishaps in the field. Remind students of the behaviors expected of them while in the field. Remind them to return permission slips!

6. If time allows, show one of the following films:
   Hubert Duprat
   Link: https://www.youtube.com/watch?v=jID1_GwxiE0
   PBS Deep Look - Dragonfly
   Link: https://www.youtube.com/watch?v=EHo_9wnnUTE

II - Sampling Field trip to Judd Creek

(75 min)

Goals:

- Understand sampling methods in the field.
- Conceptualize life conditions for macroinvertebrates in the creek.
- Determine the impact of various physical characteristics in the creek.

Objectives:

- Assist Vashon Nature Center scientists using methods to sample benthic macroinvertebrates.
- Play the game Macroinvertebrate Mayhem from the Project WET curriculum (a game of tag simulating the effects of environmental stressors on macroinvertebrates; instructions in appendices)
- Observe the physical characteristics of the creek during a creek walk and through quiet contemplation in sit spots.

Materials:

- Stream survey equipment:
  Sampling net (1, plus one back up if possible)
  Agitating tool- a weeding tool, screwdriver or hand shovel work well (2)
  Sample collection tubs (3-4)
  Sample jars (3-4)
  Wolman pebble count grid (1)
  Macroinvertebrate field guides (6-8)
  Hand-held loupes (6-8)
  Folding Table (1)
  Petri dishes (10-12)
  Ice cube trays (3-4)
- Macroinvertebrate Mayhem equipment:
  Coffee sacs or pillow cases (6)
  Dry erase board (1)
  Dry Erase pens (2-3)
  ID labels for MI groups (1 per student)
  Whistle (1 for lead instuctor)
  200' rope (1)
  Cones (4)

II - Sampling Field trip, Background Information

Though it can be logistically challenging to get students off campus and into the field—or in this case, stream—with proper planning, a field trip can be fun and will accomplish many of the unit objectives.

Well in advance of the scheduled field trip:

- Obtain permission from the school.
- Arrange for bus transport.
- Send home and collect permission slips.
- Line up parent and paraeducator chaperones.

At the end of the introduction lesson, which precedes the field trip, prepare students for what to expect during the field trip. (See Introduction Unit, Teaching Methods #5 on page 11.) Students will spend over an hour outside without direct access to bathrooms; advise towards weather appropriate clothing. Suggest students pack a change of clothing or extra socks to keep in their locker at school on the day of in case of any mishaps in the field. Remind students of the behaviors expected of them while in the field.

Day of:

- Allow for plenty of time for transitions.
- Schedule 15 minutes each way for bus transportation
- Schedule a minimum of 1 hour and 15 minutes for student time on-site.

Timeline:

0-5 minutes	Unload, safety overview, and introductions
05 - 25 minutes	Play MacroInvertebrate Mayhem (entire class)
25 - 65 minutes	Station work (two small groups)
65 - 70 minutes	Wrap up (entire class)
70 - 75 minutes	Return to bus

Group Flow:

Group A: Station 1 > Station 2 > Station 3
Group B: Station 1 > Station 3 > Station 2

As an entire class, play the Macroinvertebrate Mayhem game from Project WET; allow 20 minutes for the game.

Divide the class into two groups.

One group will go on a creek walk to examine the physical characteristics of the creek, with time for silent observation; allow 20 minutes.

The other group will sample and sort from the creek for 20 minutes. Break the sampling group into two. Spend half of the time sampling with one group while the other group looks at and sorts samples already placed in observation tubs by the scientists (for the first group) or by the prior group. Switch after 10 minutes so all students get to both sample and sort.

II - Sampling Field trip, Teaching Methods

Unloading, Safety and Class division (0-5 minutes)

*Prior to leaving school grounds, review Leave No Trace and SOLE (see appendices). Students will be dropped off at the Judd Creek trailhead with the chaperones.

1. Move the group off the road, down the trail to the South bridge. Station lead educator on the bridge and ask students to stay off of it until after the introduction.
2. Review safety expectations
   NO ONE in the creek unless instructed by Vashon Nature Center staff or volunteer.
   STAY ON THE TRAIL.
   Play fair in the game.
3. Lead entire group to station 3- Macroinvertebrate Mayhem. After the game, divide the class into two groups. The two small groups then divide the time remaining between stations one and two. At station one, the small group breaks into two smaller groups. Half of the time is spent sampling and half of the time is spent looking at the specimens.

Station 1 (20 minutes with large group) **Macroinvertebrate Mayhem**
(See appendices for attached lesson plan from Project WET.)

1. Game Set-up:
   Use the rope to create a mock stream bed in a field: 50' x 25' is about right for a class size of 25. Use orange cones to mark the corners.
2. Introduce game: This game simulates the changes in a stream macroinvertebrate community when environmental stressors are introduced. Point out playing area boundaries
3. Review what a Macroinvertebrate (MI) is:
   Organisms without backbones, large enough to be seen with the naked eye.
4. Give examples of MI
   Stoneflies, Mayflies, Caddisflies, Dragonflies, Midges, Black flies...
5. Encourage students to give examples of environmental stressors and their effects. Hand a stressor card to the students who provide the right examples (up to four students depending on the class size).
   Urban/agricultural run-off can change chemical composition of the stream to make it unlivable for many.
   Sewage and fertilizers can increase algae growth which heavily consumes oxygen making it unavailable for other organisms.

Land-use changes can increase the sediment carried by the stream, choking out certain organisms.

6. Ask students if all MI react to these stressors in the same ways. Go on to discuss tolerant vs. intolerant organisms.
   Tolerant (can withstand poor conditions)—true flies, worms, maggots
   Adaptive (prefer good water quality but tolerate poor conditions)—dragonflies, damselflies
   Intolerant (need good water)—stoneflies, mayflies, caddisflies
7. Explain the game hindrances for these three Orders of intolerant MI
   Stoneflies: four steps and then a push up
   Caddisflies: hop in the coffee sac
   Mayflies: spin
8. Hand out MI cards to the remaining students aiming for about four of each Order. Explain that they will act as the MI on their card. Adjust numbers of organisms of each type as multiple heats are played to illustrate varying effects different impacts on creek MI populations.
9. Count the population of each Order before and after each heat. On the whiteboard, chart the number of organisms at the start and the end of each round.
10. Assemble MI groups on one end of the playing field and the stressor at midfield or in various "reaches" of the stream. When the round begins, the stressor can tag any MI and they should sit down and flip their card over to become a tolerant organism.
11. Play three successive rounds. Each one should begin with a higher number of tolerant organisms.
12. Begin a new game, if time allows increasing the number of environmental stressors.

Station 2 (20 minutes per small group) **Creek Walk**

Walk a short distance up the stream pausing to elicit observations from the students regarding the physical characteristics of the stream listed below. Before turning back down the trail, allow time for each student to find their own spot along the creek for three minutes. Talk about the abundance and diversity of the riparian vegetation on the return hike. Point out key native plants and discuss their significance as time allows.

Physical Characteristics of the Stream:

1. Riffles and Pools
   Streams need a balanced number of pools and riffles to support healthy MI and fish populations. Riffles are areas where oxygen is added to rapid moving water.

Pools are areas where the water slows, eddies, and deepens, providing fish with resting and hiding places.

2. Large Woody Debris (LWD)
   Large woody debris performs many functions in the creek. It helps diversify the habitat of the creek; slows water flow; creates pools; water spills over it, increasing the available oxygen in the creek; it provides cover and protection for small fish; it decomposes to become a food source for shredding MI organisms.
3. Cover (Temperature)
   Cover can be provided by forest canopy, overhanging low vegetation, and large woody debris. It provides protection from predators, aids in keeping water temperatures cool, and provides areas for insects to lay their eggs and to forage for food.
4. Substrate
   Substrate refers to the bottom of the creek. It is where most macroinvertebrates focused on in this unit live. Substrate can be affected by high flow rates, sedimentation, and changes in riparian vegetation.
5. Riparian Vegetation ID on return walk

Common Native Riparian Vegetation of Vashon:

Douglas Fir (*Pseudotsuga menziesii*)
Western Red Cedar (*Thuja plicata*)
Western Hemlock (*Tsuga heterophylla*)
Big Leaf Maple (*Acer macrophyllum*)
Red Alder (*Alnus rubra*)
Black Cottonwood (*Populus trichocarpa*)

Salmonberry (*Rubus spectabilis*)
Oceanspray (*Holodiscus discolor*)
Salal (*Gaultheria shallon*)
Indian Plum (*Oemlaria cerasiformis*)
Sword Fern (*Polystichum munitum*)
Stinging nettle (*Urtica dioica*)

Suggested Resources:

Pojar, Jim and Andy Mackinnon. Plants of the Pacific Northwest Coast. Lone Pine Publishing, Vancouver B.C.
Available in most bookstores or order online. Excellent for educators.

Vashon Maury Island Field Guide
Available online at http://vashonnaturecenter.org/buy/ Great for students.

<u>Station 3 (20 minutes per small group)</u> **<u>Macroinvertebrate Sampling</u>**

Set up: Prepare the sampling equipment near the edge of the stream. Choose a location which allows students reasonable stream access without disrupting streamside vegetation and the bank. Adjacent to the sampling reach, set up a table to examine specimens collected during sampling.

Divide the group of students into two smaller groups. Half of the time is spent sampling and half of the time is spent looking at the specimens.

At the creek, explain the sampling equipment. Demonstrate techniques for sampling, inviting student participation. Assign roles to the students. Agitate the substrate for 60 seconds allowing as many students as possible to take a turn agitating and holding the collection net. Have other students track the time. Have students assist in transferring the sample from the net to a tub.

At the table, allow for students to observe the bulk sample in the collection tub. Discuss the different individual specimens. Highlight the different Orders and identify different characteristics, feeding functions, and species present.

<u>Wrap-up</u>

Whether a stream is healthy or not cannot be determined just by looking at the water. Characteristics like temperature, flow rate, sedimentation, and the amount of pollution present can all change very quickly. Only by looking at the biological characteristics (the Macroinvertebrate populations and community types) of the creek can we begin to understand the health of the creek over a long period of time. Actions anywhere in the watershed can affect the health of the creek and living creatures in it.

III - Lab Introduction

(50 min)

Goals:

- Introduce the taxonomic classification system.
- Identify the distinguishing characteristics between taxonomic Orders.
- Familiarize with the concepts, methods, and equipment to be used during the sorting lab
- Introduce the Puget Sound Benthos database and the Benthic Index of Biotic Integrity (B-IBI)

Objectives:

- Examine the Tree of Life to learn how both invertebrates and humans are classified.
- View slides showing the different taxonomic orders focused on in this unit
- Complete a group quiz on the distinguishing characteristics between
- Observe a mock lab session
- Explore the Puget Sound Benthos database and find B-IBI scores

Materials:

1. Powerpoint presentation for lab introduction
2. Lab supplies to demonstrate methods and materials
    - Labeled samples from creeks
    - Sorting tubs (1)
    - Petri dishes (6)
    - Ice cube trays (1)
    - Forceps (1)
    - Pipette/Droppers (1)
    - Microscopes (1)
    - Macroinvertebrate Identification guides (1)
    - Dichotomous keys (1)
    - Labeled sample jars for sorted specimens (5 for each creek sampled)
    - Laminated sheet of plain white paper (1)

III - Lab Introduction, Background Information

McMurray students assist Vashon Nature Center scientists in monitoring island streams. Annual water quality monitoring is done through sampling the benthic macroinvertebrate populations in island creeks. All of the data from these studies are submitted to the Puget Sound Stream Benthos Database (see link in appendices), which collects data region wide and scores stream health.

Benthic macroinvertebrates are used to determine the health of streams for many reasons. They are COOL: collectable, observable, omnipresent, and learnable. Across species, there is a wide range of tolerance to poor water quality. This, coupled with their long lifespan in the creek (some up to two to three years) makes them reliable indicators. By examining their taxonomic orders and feeding functions, physical and chemical characteristics of the creeks can be inferred.

Taxonomic classification of life allows us to sort out the connections and distinctions between all forms of life. Taxonomy was created long ago by Carolus Linnaeus (1701 - 1778). He was a Swedish scientist who grouped living things into hierarchical categories based on observable characteristics. The hierarchy consists of eight levels, which move from general to more specific as they progress. The latest level, Domain, was added in 1990 and includes three categories.

Domain- 3 domains: Archaea, Bacteria, Eukarya
Kingdom - 6 kingdoms: Animalia, Plantae, Fungi, Protista, Archaea, and Bacteria
Phylum - Each of the 6 kingdoms has a different number of phylums. Both humans and macroinvertebrates are members of the animal kingdom (Anamalia). Anamalia contain 35 phylum, including Chordata (organisms with a nervous cord, like humans) and Arthropoda (including macroinvertebrates).
Class - There are 5 major classes of Arthropodoa including arthropods, insects, centipedes, millipedes, arachnids and crustaceans. Chordata contains 7 classes including reptiles, amphibians, avains (birds) fish, and mammals.
Order - The number of orders of mammals is still debated, with expert opinions ranging from 19 to 26. Some orders of mammals include primates, cetaceans, rodents, and bats. There are 30 orders of Insects. The orders this unit will focus on include Plecoptera, Ephemeroptera, Trichoptera, and Diptera.
Family – Family, Genus, and Species represent a finer scale of details about the of differences between organisms. For example: Humans are in the Primate order and the Hominidae family; our genus is Homo and sapien is our species.
Genus - Humans are in the genus Homo.
Species - Humans are of the species: sapiens.

Taxonomic classification is a system for organizing life on Earth. Sometimes called the Tree of Life, it can be thought of as an extended family tree. In a traditional family tree the trunk represents a distant ancestor and each branch a successive generation until a sprouting twig represents your parent and you are the leaf. The taxonomic family tree has its roots in domain and kingdom is the trunk branching out as phylums, and then classes, followed by orders, families, genuses, and finally, species.

Taxonomic Tree:

Kingdom > Phylum > Class > Order > Family > Genus > Species

Human Family Tree:

Anamalia > Chordata > Mammalia > Primate > Hominidae > Homo > sapiens

Macroinvertebrate Family Tree (as far as it is explored in this unit):

Anamalia > Arthropoda > Insecta > 4 studied in this unit include **Diptera** (true flies), **Ephemeroptera** (mayflies), **Plecoptera** (stoneflies), and **Trichoptera** (caddisflies). All other organisms found will be sorted as *Other*.

Observable characteristics distinguish the different macroinvertebrate orders.

Ephemeroptera (mayflies) have 2 or 3 tails, abdominal gills, and a thorax which is fused. **Plecoptera** (stoneflies) have 2 tails, gills on their thorax or head and sometimes under their arms, and a thorax which is divided into three segments. **Trichoptera** (caddisflies) are wormy looking, with three sets of legs. Sometimes there is an armored covering on the first three segments where the legs are. Many build a case from sticks, pebbles, or other materials to protect their soft bodies. **Diptera** (true flies) are variable. They can have a distinct bowling-pin shape, a segmented worm-like appearance but with small prolegs and they are long and fleshy. **Other taxa** (specimens) can include aquatic worms, beetles (which are often confused with caddisflies but have a hard shell over all their segments), scuds, clams, snails, and other insects.

During the lab students will use tools to handle and sort samples from local creeks. These samples contain dead specimens which have been preserved with an ethyl alcohol solution. While the samples will be prepared properly to ensure there is no exposure to toxic chemicals, the vapors can be off setting for some students. Students will be using tools to handle actual specimens.

Once specimens have been sorted to order (or further to genus when it is possible!) in the lab, they will be placed into labeled sample jars and sent to the Puget Sound Stream Benthos Database lab where scientists will give each creek a health score based off of the composition of specimens collected.

III - Lab Introduction, Teaching Methods

1. Set up a mock lab station in the front of the classroom for students to observe. Include all of the materials to be used in the lab.

2. Refresh students on the Puget Sound Stream Benthos database. What is it? How do they take our samples and create creek health scores? Explore the site for scores of local creeks over time.
   Link:
   https://www.pugetsoundstreambenthos.org/Biotic-Integrity-Map.aspx?Stream-Area=Shinglemill%20Creek&d=4

3. Review why we use macroinvertebrates to examine stream health.

4. Explore questions for potential analysis through the sorted samples. Possible examples include, comparing how a single creek changes over time; how two different creeks compare during the same year; how a particular creek has responded to an influencing factor such as restoration, extreme weather conditions, or contamination.

5. Introduce taxonomic classification.

6. Examine the distinguishing characteristics between different orders of benthic macroinvertebrates.

***Activity: As a class take the [Macroinvertebrate Identification Pop Quiz](http://www.nwnature.net/macros/macros_set_a/macros_set_a.html)* online.**

Link: http://www.nwnature.net/macros/macros_set_a/macros_set_a.html

7. Explain the procedure for sorting the specimens. Show the set-up for each sorting station. Explain each tool, how to operate it, and what is expected from students regarding the use of this equipment.

8. Demonstrate collection techniques. Each group will have a large sample tub. The petri dishes labeled to Order remain in the middle on the laminated paper for best visibility and easy access by all students. Students use the forceps or pipettes to collect a specimen from the tub and place it into their personal petri dish. Observe the specimen. When the taxonomic Order has been determined, place it in the proper petri dish labeled by creek and Order (on the laminated paper in the

center of each sorting station).

9. Explain the Illustration Station. It is used to connect the right and left sides of the brain enabling students to see details in anatomy and distinguishing characteristics which otherwise may go unobserved. It can also be used as an opportunity to discuss the field of scientific illustration.

10. Explain the Closer Look Station. It is staffed by expert scientists and used to allow students to explore a particular specimen in depth. This station can also be used to introduce dichotomous keys.

11. Field any questions for the upcoming lab.

V - Sorting Lab

(50 min)

Goals:

- Sort collected invertebrate samples to taxonomic Order and to Genus and Species when possible.
- Develop and practice fine-scale observation skills necessary for scientific work.
- Demonstrate an example of real world science techniques

Objectives:

- Sort specimens using collected samples from individual creeks; use identification keys, tools, and microscopes.
- Observe individual specimens up close at two stations: an illustration station and a microscope station with experts.
- Follow standardized protocols to ensure quality work is conducted.

Materials:

1. Powerpoint presentation for lab introduction
2. Lab supplies for entire class
    - Labeled samples from creeks
    - Sorting tubs (1 per group)
    - Petri dishes (5-6 per group + 1 per student)
    - Ice cube trays (4-6)
    - Forceps (1 per student)
    - Pipette/Droppers (1 per student)
    - Microscopes (2 per group)
    - Paper, plain printer paper or similar for sketching (1 sheet per student)
    - Pencils (6-8)
    - Macroinvertebrate Identification guides (10)
    - A Key to Common Aquatic Invertebrates of Vashon Island, Washington (2)
    - Labeled sample jars for sorted specimens (5 for each creek sampled)
    - Laminated sheet of plain white paper (1 per group)

V - Sorting Lab, Background Information

During the lab students will use tools to handle and sort samples from local creeks. These samples contain dead specimens which have been preserved with an ethyl alcohol solution. While the samples will be prepared properly to ensure there is no exposure to toxic chemicals, the vapors can be off setting for some students. Students will be using tools to handle actual specimens.

To conduct the lab:

1. Prepare the samples ahead of time.
2. Divide the class into groups of four ideally.
3. Each group will have its own sorting station.
4. Prepare space for the Illustration Station.
5. Prepare space for the Closer Look Station.
6. Allow room for the final sorted samples to be collected. Each order from each creek will have its own collection jar. Label the jars with the creek name, year, and taxonomic order.

Preparing Samples for the Classroom:

Samples are preserved in 70% or stronger mix of ethyl alcohol after they are collected from the field. This is a toxic chemical requiring adequate ventilation while handling. Before students arrive, process the samples to reduce the exposure to the alcohol solution by following the procedure below:

1. Set up space under a ventilation hood or outside to ensure adequate ventilation.
2. Label a clean sample tub for each of the sample jars to be processed.
3. Open a sample jar from one creek.
4. Place a clean sample tub onto a flat and sturdy work space.
5. Using a 0.5mm sieve, strain the sample from the solution by pouring the contents of the sample jar through the sieve and into a clean sample tub. The sample will remain in the sieve while the ethyl alcohol ends up in the tub.
6. Rinse the sample with a small amount of freshwater.
7. Find the clean sample tub matching the sample jar you are processing and place it onto a flat and sturdy work space.
8. Dump the sample from the sieve into the tub.
9. Rinse the sieve with a squirt bottle, gathering all of the remains of the sample, and rinsing them into the sample tub.
10. Add water to the tub to suspend the sample. The water should be as cold as possible to slow decomposition of the samples once they have been removed from the alcohol.
11. Decontaminate the sieve in between each sample.
12. Repeat with all samples making sure the sample jar labels and tub labels match.

V - Sorting Lab, Teaching Methods

1. Give students an outline of the classroom flow for the period.

2. Review the procedures for sorting samples and the expectations for the illustration station and closer look station:

   Working in small groups, students will sort specimens from collected samples. Each group will have their own microscope, field guide, a laminated sheet of white paper, and five petri dishes labeled to order. Each student should have their own set of forceps, an unlabeled petri dish, and their own laminated sheet of white paper.

   The Illustration Station is used to connect the right and left sides of the brain enabling students to see details in anatomy and distinguishing characteristics which otherwise may go unobserved. It can also be used as an opportunity to discuss the field of scientific illustration. The station should have the paper, pens, coloring pages, and other reference materials as needed.

   The Closer Look Station is staffed by expert scientists and used to allow students to explore a particular specimen in depth. This station can also be used to introduce dichotomous keys. The station should have the two copies of the A Key to Common Aquatic Invertebrates of Vashon Island, Washington, and microscopes.

Activity: As a class take the [Macroinvertebrate Identification Pop Quiz](http://www.nwnature.net/macros/macros_set_a/macros_set_a.html) again.
Link: http://www.nwnature.net/macros/macros_set_a/macros_set_a.html

3. Divide the class into groups of four (ideally).

4. Allow for ten minutes at the end of the period to for the entire class to come together and share stories.

5. Divide the remaining time so all groups rotate through the Illustration Station and The Closer Look Station. Determine the best way to manage time based off of the classroom dynamics. Some classes benefit from having a timer set to determine the exact time spent at each of the Expert and Illustration stations. Other groups work better when students can flow between stations more organically. Either way, have students return to their sorting station when they are finished at the illustration and expert stations.

6. Use the last ten minutes of class to share stories and specimens as a whole class.

VI - Analyzing Sorted Creek Samples

(50 min)

Goals:

- Quantify the number of specimens collected from the sorted samples.
- Understand the concepts of diversity and abundance, as well as the differences in what these terms measure.
- Assess the overall health of the watershed and determine the factors affecting the water quality.

Objectives:

- Working in small teams, groups will count the abundance within different Orders and report their findings to the class.
- As a large class, students will analyze and compare the abundance and diversity of the two different streams.
- Using the macroinvertebrate population collected, students will infer the physical conditions of their creeks and assess the potential impacts affecting water quality in the creeks.

Materials:

- Sorted samples from both creeks, labeled by creek and order
- Forceps (one per student)
- Petri dishes (5-6 per group + 1 per student)
- Student worksheets

VI - Analyzing Sorted Samples, Background Information

By analyzing benthic macroinvertebrate samples from a creek, inferences can be made regarding the physical and chemical conditions of the creek environment. In addition, an image of land use within the watershed can be created from the population of macroinvertebrates in a specific sample.

The samples we have collected and sorted are sent to Rhithron Labs in Missoula, Montana. After double-checking our classifications, the lab loads our data onto the Puget Sound Stream Benthos website. Creeks are scored based on a variety of different metrics or grading criteria applied to the sample. The metrics include total taxa richness, ephemeroptera richness, plecoptera richness, trichoptera richness, intolerant taxa richness, clinger taxa richness, long lived taxa richness, percent tolerant, percent predator, and percent dominance. For a complete definition of each metric, visit the Puget Sound Stream Benthos About the B-IBI webpage (see link in Appendices).

The B-IBI was developed by a fish biologist at the UW named James Karr. His expertise was not invertebrates, but he used observation and reasoning skills to create this index that is now a standard across the world for measuring stream health.

The index uses metrics for grading creeks. A metric is a system of measurement. The lab uses these metrics to infer what the conditions of each specific creek are and provide possible management techniques meant to improve creek health for wildlife and humans. In this unit we will focus on analyzing a portion of the metrics used by the lab. They are:
(Most of the following information is taken directly from the Puget Sound Stream Benthos database.)

Diversity: The biodiversity of a stream declines as flow regimes are altered, habitat is lost, chemicals are introduced, energy cycles are disrupted, and alien taxa invade. Diversity refers to all of the different species within a specific metric or across the entire sample as a whole. We will measure a component of diversity called taxa richness which is just the total number of different taxonomic groups present in the sample (i.e. orders, genus, species depending on how far down we can get the identification).

Abundance: The abundance in a sample refers to the total number of organisms. It is a count of all taxa within a metric or across the entire sample as a whole.

Plecoptera richness and abundance: Stoneflies are the first to disappear from a stream as human disturbance increases. Many stoneflies are predators that stalk their prey and hide around and between rocks. Hiding places between rocks are lost as sediment washes into a stream. Many stoneflies are shredders and feed on leaf litter that drops from an overhanging tree canopy. Most stoneflies, like salmonids, require cool water temperatures and high oxygen to complete their life cycles.

Ephemeroptera richness and abundance: The diversity of mayflies declines in response to most types of human influence. Many mayflies graze on algae and are particularly sensitive to chemical pollution that interferes with their food source. Mayflies may disappear when heavy metal concentrations are high while caddisflies and stoneflies are unaffected. In nutrient-poor streams, livestock feces and fertilizers from agriculture can increase the numbers and types of mayflies present. If many different taxa of mayflies are found while the variety of stoneflies and caddisflies is low, enrichment may be the cause.

Trichoptera richness and abundance: Different caddisfly species (or taxa) feed in a variety of ways: some spin nets to trap food, others collect or scrape food on top of exposed rocks. Many caddisflies build gravel or wood cases to protect them from predators; others are predators themselves. Even though they are very diverse in habit, taxa richness of caddisflies declines steadily as humans eliminate the variety and complexity of their stream habitat.

Diptera richness and abundance: True flies are tolerant animals which are present at most stream sites, but as disturbance increases, they represent an increasingly large percentage of the population. They are the opposite end of the spectrum from intolerant (sensitive) taxa.

Other richness and abundance: Other taxa includes all of the organisms collected in the sample which are not classified in one of the orders we are focusing on in this unit. That means any taxa collected which is not plecoptera, ephemeroptera, trichoptera, or diptera will be in this sample. Although our study is not focusing on these taxa, they can tell us important information about the creek.

VI - Analyzing Sorted Creek Samples, Teaching Methods

1. Review the Puget Sound Stream Benthos database. (Approx. 5 minutes)
   Remind students of the man who designed it, James Karr, and his application of observation and reasoning in a field he knew very little about. Define the terms of diversity and abundance. Discuss how they are different yet related (using a soccer team analogy works well: an abundance of players is needed to play, a diversity of skill sets and abilities is needed for a strong team). Explain the idea of metrics to grade creeks and introduce the metrics we will use as a class (a subset of the entire suite used by the lab).

2. Compare the sorted samples from each creek. (Approx. 10 minutes)
   Set up two stations, one for each creek. Line up the sample jars in the same order by creek. This allows for students to cross-compare the different Orders as well as the entire creek population. Invite students to write their observations on the board. Return students to their desks and discuss their observations as a class.

3. In small groups examine an order of insect from one of the creeks. (Approx. 10 minutes)
   Each group should be given a different order from a different creek and focus on that one. Together the small group must (1) read their metric and discuss what it helps to quantify, (2) count the total abundance of their sample portion, and (3) count the diversity of their sample portion.

4. As a large class, *Turn and Talk:* (Approx. 5 minutes)
   (1) compare the same orders from the different creeks and (2) discuss what the possible causes may be for any differences abundance and or diversity within the different sample portions and what this implies in terms of creek health.

5. Invite a representative from each group to report their numbers to the class. (Approx. 15 minutes) Discuss as a class each metric and what can be inferred from the numbers. Encourage suggestions for possible land-management changes to be made based on the results.

VII - Claim, Evidence, and Reasoning; Poster

(Five, 50 min periods)

Goals:

- Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. (NGSS MS-LS2-1)

- Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of the ecosystem. (NGSS MS-LS2-3)

- Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. (NGSS ELA/Literacy: SL.8.4)

- Determine which creek is healthier, based on evidence (data) and reasoning (how/why) to support a claim (statement) in a C-E-R Scientific Argument.

Objectives:

- What do scientists do and how do they do it?
- How do scientists work together to solve problems?
- Effectively utilize a dichotomous key unique to Vashon streams, and aquatic macroinvertebrate field guides.
- Research the “riparian area” and the needs of different Macroinvertebrate Orders as they relate to “functional feeding groups”
- Effectively utilize the Claim-Evidence-Reasoning system

Materials:

- Creek Analysis Worksheet (1 per student)
- Dichotomous key for Vashon stream macroinvertebrates (2)
- Field Guides for Vashon stream macroinvertebrates (10 - 12)
- “Stream Quality Scientific Argument” template (1 per student)
- Claim, Evidence, and Reasoning (C-E-R) assessment rubric (1 per student)
- Drawing paper (1 per student)
- Pencils and erasers (1 per student)
- Black and colored pens (multiple per student)
- Rulers and meter sticks (1 per student)
- Giant sticky note for team poster (1 per group)
- Chromebooks for research (1 per student)
- Journals for taking notes (1 per student)

VII - Claim, Evidence, and Reasoning; Poster, Background Information

Basic skills:
The ability to think through a problem, alone or with a group, and then present one's argument backed by evidence, is a valuable life skill. The Claim, Evidence, and Reasoning (C-E-R) model is designed to help students achieve this skill. In the C-E-R model, students will be asked to answer a question both as an individual and as a member of a small group. The exact question may change over time, as different creeks are sampled and compared. For example, students may be asked to compare different streams to one another, or to compare the same stream over time as years of data are accumulated. Students will use evidence collected from the sorting day, being sure to include the terms diversity and abundance, tolerant and intolerant, and other observations.

Students will create a poster to demonstrate this popular method for sharing scientific research. They will do further research into the feeding functions of a particular macroinvertebrate focusing in on its particular role in the riparian area and its needs in terms of physical creek characteristics. Teams will work from one of the four Orders: Plecoptera, Ephemeroptera, Trichoptera, and Diptera, plus the Other category. Feeding functions include: predators, scrapers, shredders, gatherers/collector and filter feeders. They will present their findings in a scientific poster.

Another important science skill is using a dichotomous key for classification of living organisms. A key specific to Vashon Island Stream Macroinvertebrates was developed specifically for this Citizen Science Program through Vashon Nature Center and PIE. The key has excellent photos and a logical progression of the four Orders of macroinvertebrates, as well as other species outside of the four Orders. Students who want to go further, can try to key out their finds to species. Use of a dichotomous key fosters observation and critical thinking skills.

Citizen science and application of scientific knowledge:
In addition to learning important scientific reasoning and measurement skills, students participating in this unit are participating in citizen science. Citizen science is the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists.
Since 2014, McMurray science students have worked alongside scientists to sort invertebrate data from Shinglemill Creek. The first two years of collected data revealed potential impacts of storm-water runoff to the Shinglemill watershed. Students in 2014

and 2015 presented their findings to the local King County Groundwater Protection Committee, a citizen advisory board to King County. Vashon High School (VHS) students also helped by working with Vashon Nature Center, King County, and Washington Department of Ecology to trace the pathway of storm-water runoff from a downtown Vashon parking lot directly into Shinglemill Creek. In addition, VHS students helped McMurray students with the student presentations to the Groundwater Committee.

In response to these student findings, the King County Groundwater Protection Committee launched a multi-year effort to create a plan to improve infiltration of storm-water and reduce runoff from town. First steps included creating a pump system (in 2015) that pumped car wash run-off into a nearby field to allow it to soak into the ground slowly rather than going straight into the antiquated storm-water drain system (and the creek).

In 2018, funding was secured to start a large storm-water reduction project in the IGA parking lot, including installing rain gardens and replacing impervious pavement with pervious pavement! Plans to expand this storm-water remediation to other creeks that drain Vashon town are in the works. In subsequent years, students will be able to monitor Shinglemill Creek and see if the storm-water remediation effort is improving creek conditions!

VII - Claim, Evidence, and Reasoning; Poster, Teaching Methods

1) Review: What is a benthic macroinvertebrate? Why are they important? What do they tell us about the health of a creek?

- The immature phase of flying insects, which spend this entire cycle of their life under water.
- A vital food source for young salmon, other freshwater fish, birds, and other invertebrates.
- Wide ranging in their ability to tolerate poor water quality.
- Long lived, which makes them excellent indicators of the long-term picture of stream health (especially compared to physical and chemical characteristics, which can change quickly and vary widely).
- Essential in the decomposition of organic matter in the stream.
- Critical to the overall complexity of an ecosystem.

2) Review the results of data from the day of sorting, using the graphic organizer (“Which creek is healthier?”) notes from that day:

- Read the description of the taxa on your sheet: What does it need to survive?
  Turn and Talk.
- What is the <u>abundance</u> and <u>diversity</u> of your order for the creeks you were assigned? How do they compare?
  Turn and Talk.
- Now look at the totals of each order of macroinvertebrate at the bottom of your sheet. Look at the other columns. How do they compare?
- *Class discussion*: Which creek do you think is healthier? Why?
  Probe for reasoning. Discuss different roles of macroinvertebrates.
- Sometimes it’s hard to make a definite conclusion based on the information we have. The important thing is for students to backup their claims with evidence.
- In addition to the C-E-R model, an important step is to brainstorm alternative explanations to the patterns found in the data. Ask students to brainstorm other possible reasons for their claim.

3) Make these resources available to students in the classroom: dichotomous keys, field guides, and Chromebooks to take journal notes about what each type of macroinvertebrate needs to thrive in a creek.

4) Discuss how we could make a bar graph using the data on the sheet, and model it on the document camera. Explain that a graph helps organize data so it is easier to see.

5) Show students the rubric for scoring the C-E-R “Guide for Scientific Explanations”. Explain that they will be graded using this rubric. Remind them that they can use notes in their journals and other notes.

6) Tell students that they will be ***completing their own Claim, Evidence, and Reasoning assessment during the remainder of the class period. Tell them that this is an assessment to be completed individually, so there is no talking.***

7) Explain that after the C-E-Rs are corrected, they will be working in teams to make one ***poster.*** Together students (just like scientists do) will pool their C-E-Rs and talents, and dive deeper into learning about a particular macroinvertebrate and the role it plays in the riparian system. They will be illustrating the poster to present the characteristics of the macroinvertebrate focused on as a group. If the group desires, more than one macroinvertebrate may be highlighted. See below (#11) for the requirements for the group poster.

8) Show examples of team posters from prior years to help get students started.

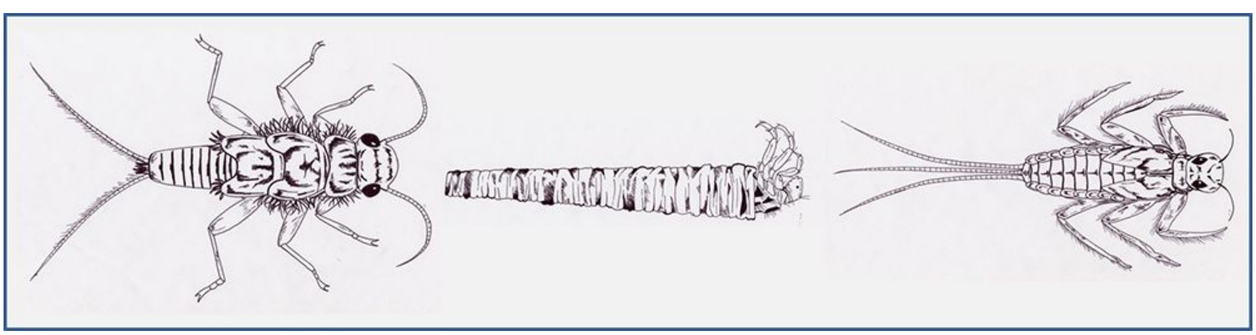
9) Make resources available to students in the classroom: dichotomous keys (online and hard copes), field guides, Chromebooks, text books for guidance in making graphs, drawing paper, pencils, colored pencils, fine tip pens, and colored pens. Students are to take notes in journals.

10) Ask students to include physical characteristics of the creek such as pools and riffles, large woody debris, pebbles, cobbles or sand, riparian area, in the drawing on the poster.

11) Requirements for the team poster:

- First and last names of all your team members and your class period.
- Title of your poster including the creek(s) name.
- Your CLAIM clearly stated.
- Your EVIDENCE, in the form of a chart or graph.
- Your REASONING statement, which links your claim to your evidence.
- Include at least 3 drawings of macroinvertebrates and show them in their natural habitat. What does it need to thrive? What is its “feeding function”? Can you show that in your drawing?
- Design the layout of the poster so it is interesting to look at and informative.

12) Prepare to present your team poster to the class. Review C-E-R Rubric. Follow the protocol for a presentation.



Appendices

Videos:

WA Dept. of Ecology Video *Sampling Macroinvertebrates in Wadeable Streams in WA State*
https://www.youtube.com/watch?v=IuNn4VqFtJI

Hubert Duprat Video *Caddisfly Jewelry*
https://www.youtube.com/watch?v=jID1_GwxiE0

PBS Deep Look Video *A Baby Dragonfly Will Give You Nightmares*
https://www.youtube.com/watch?v=EHo_9wnnUTE

PBS Deep Look Video *Sticky. Stretchy. Waterproof. The Amazing Underwater Tape of the Caddisfly*
https://www.youtube.com/watch?annotation_id=annotation_2631367953&feature=iv&src_vid=svpP4HdsNI8&v=Z3BHrzDHoYo

USGS Video *A Study in Stream Ecology*
https://www.youtube.com/watch?v=67G5jr_t_iM

USGS Video *Effects of Urbanization on Stream Ecosystems*
https://www.youtube.com/watch?v=BYwZiiORYG8

Online Links:

Data Entry and Review

Puget Sound Stream Benthos
http://pugetsoundstreambenthos.org/Default.aspx

Online Interactive Identification Quiz

Macroinvertebrate Identification Pop Quiz
http://www.nwnature.net/macros/macros_set_a/macros_set_a.html

Field Guides

The Xerces Society Macroinvertebrates of the Pacific Northwest
https://xerces.org/macroinvert-pnw/

Freshwater macroinvertebrates from Streams in Western Washington and Westeron Oregon
http://nwnature.net/macros_guide/guide.html

A Key to Common Aquatic Invertebrates of Vashon Island, Washington
http://vashonnaturecenter.org/wp-content/uploads/2018/09/VMI_AQ_INV_KEY_2017.pdf

Laminated Field Guide to Vashon Maury Islands

http://vashonnaturecenter.org/buy/

Resources

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1. Mock Stream Setup Cards
2. Macroinvertebrate Mayhem, Project Wet
3. LNT Guidelines
4. SOLE Infographic
5. Macroinvertebrate color pages
6. Intolerant Macroinvertebrate Handout
7. Tolerant Macroinvertebrate Handout
8. Worksheet - Macroinvertebrate Close up
9. Worksheet - Creek Analysis
10. Worksheet - Lab

Definition of Terms

Abundance
The abundance in a sample refers to the total number of organisms. It is a count of all taxa within a metric or across the entire samples a whole.

Benthic macroinvertebrate
Aquatic animals without backbones that are visible to the naked eye.

Biological stream characteristics
These can tell us about the health of the steam over time. They include the types and variety of benthic macroinvertebrates found in the creek.

Chemical stream characteristics
These can tell us about the health of the steam over a short period of time since this information is highly variable and can rapidly change. They include the pH, the available oxygen, and the temperature.

Claim Evidence Reasoning Argument (CER)
As part of the scientific inquiry process, scientists will make claims based on observable evidence and will clarify with reasoning which links the evidence to the claim.

Claim
A statement based on observable evidence.

Cobble
The rocks and sand on the bottom of the stream bed.

Diversity
For this unit, we are quantifying one component of diversity called **taxa richness**—the number of different species (or higher taxonomic groups) within a specific metric or across the entire sample as a whole. The taxa richness of a stream declines as flow rates are altered, habitat is lost, chemicals are introduced, energy cycles are disrupted, and alien taxa invade.

Diptera
This describes an order of macroinvertebrates. Commonly termed True flies.

Ephemeroptera

This describes an order of macroinvertebrates. Commonly termed Mayflies.

Evidence
Data and observations used to support a claim in a claim evidence reasoning argument.

Filter feeders
This describes a macroinvertebrate feeding function. These organisms eat by filtering food out as it passes along in the water. Examples include: net-spinning caddisfly

Gatherers/Collectors
This describes a macroinvertebrate feeding function. These organisms eat by gathering and collecting organic material in the creek, like leaves and twigs. Examples include: midge-fly larvae.

Index of Biotic Integrity
A system for scoring creek health, created by a UW Fisheries Biologist, James Karr. It is used by the Puget Sound Stream Benthos Lab, which analyzes the data we collect and sort.

Large Woody Debris (LWD)
Term for wood material in the stream bed. It can be in contact with the ground and water or suspended over it. LWD helps create pools and riffles, increases oxygenation, shades the water, and provides hiding places for organisms in the creek.

Physical stream characteristics
These can tell us about the health of the steam over a short period of time since this information is highly variable and can rapidly change. These characteristics include the number of pools and riffles, amount of large woody debris, substrate size, and type and abundance of riparian vegetation communities.

Plecoptera
This describes an order of macroinvertebrates. Commonly termed Stoneflies.

Predators
This describes a macroinvertebrate feeding function. These organisms predate other macroinvertebrates. Examples include: golden stonefly and dragonfly.

Reasoning statement
Statement which links evidence to a claim statement in a scientific claim evidence reasoning argument.

Riparian area

The interface between the upland habitat and the aquatic zone of the creek characterized by moist soils and moisture-loving plants.

Riparian vegetation
Moisture-loving plants growing along the edge of the stream and within the riparian area. They shade the creek, which keeps water temperatures low and provides protective cover for prey animals to hide under in the creek. Riparian vegetation also provides rearing and foraging habitat for insects.

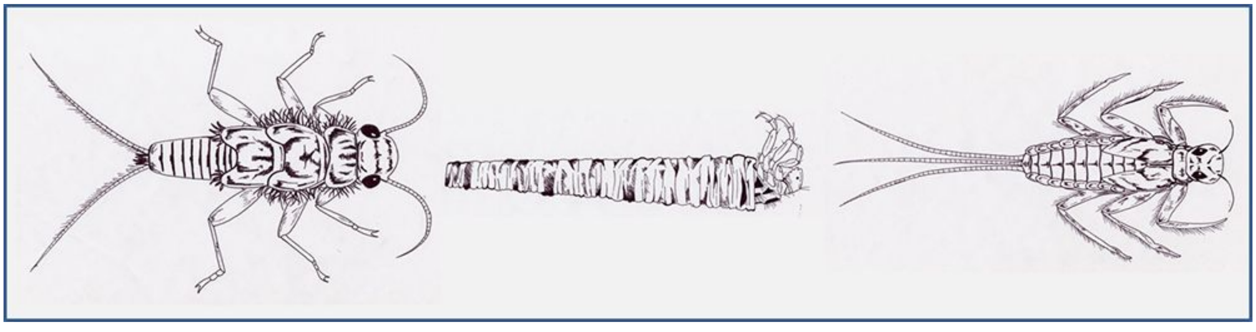
Scrapers
This describes a macroinvertebrate feeding function. These organisms eat by scraping algae from rocks and woody debris. Examples include: flat-headed mayfly.

Shredders
This describes a macroinvertebrate feeding function. These organisms eat by shredding organic material in the creek, such as leaves and twigs. Examples include: scuds.

Taxonomy
Hierarchical classification of life based on observable characteristics which can be likened to a family tree.

Trichoptera
This describes an order of macroinvertebrates. Commonly termed Caddisflies.

Watershed
An area of land from which water, sediment, and dissolved materials drain to a common water course or body of water.



Next Generation Science Standards

The Benthic Macroinvertebrate Sampling and Freshwater Quality Monitoring curriculum integrates the following Next Generation Science (NGSS) Standards:

MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-2 Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of the ecosystem.

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.