Macroinvertebrates and What They Tell us About the Water

Alaska State Science and Cultural Standards

Science Standards

A. Science as Inquiry and Process

SA Students develop an understanding of the process and applications of scientific inquiry.

- **SA1** Students develop an understanding of the processes of science used to investigate problems, design, and conduct repeatable scientific investigations, and defend scientific arguments.
- **SA3** Students develop an understanding that culture, local knowledge, history, and interaction with the environment contribute to the development of scientific knowledge, and that local applications provide opportunity for understanding scientific concepts and global issues.

Cultural Standards

B Culturally-knowledgeable students are able to build on the knowledge and skill of the local cultural community as a foundation from which to achieve personal and academic success throughout life.

- **B3** Students are able to make appropriate choices regarding long-term consequences of their actions

E Culturally-knowledgeable students demonstrate an awareness and appreciation of the relationships and processes of interactions of all elements in the world around them.

- **E2** Students are able to understand the ecology and geography of the bioregion they inhabit.

Science Standards taken from Alaska Performance Standards, Department of Education and Early Development of the State of Alaska.

Cultural Standards taken from Alaska Standards for Culturally Responsive Schools, adopted by the Assembly of Alaska Native Educators; Anchorage, Alaska; February 3, 1998.

Macroinvertebrates and What They Tell us About the Water

Grade Level: Grades 6 -8

Objectives:
Students will be able to:

- Name and identify three benthic macroinvertebrates that are indicators of a healthy stream
- Explain biological monitoring is and conduct monitoring independently
- Estimate the health of a local stream and conduct field research to see if estimation was correct

Resources and Materials:

- Purchase the *Streamkeeper's Field Guide.* Available on Amazon.com.
- *Alaska Stream Team.* http://accs.uaa.alaska.edu/aquatic-ecology
- http://macroinvertebrates.org/#/ephemeroptera/heptageniidae/maccaffertium/dorsal

Teaching:
This curriculum is for the education of water quality and its relation to benthic macroinvertebrates in reference to the Yukon River Watershed. The following includes a lesson and a hands-on activity. There are also additional activities provided at the end. Feel free to adjust detail to help meet the needs of the students you are teaching.

Lesson:

This lesson includes information about biological monitoring and benthic macroinvertebrates as well as how to conduct hands-on field research. Students should take notes from the lesson as they will have to know parts of it for when they go conduct a biological assessment.

Prior to the lesson the instructor will have to:

- Identify local stream(s) for class to visit and monitor
- Gather supplies to conduct biological monitoring such as ID charts, nets (D-frame nets are preferable but aquarium net wills suffice), buckets, trays, hands lens, and forceps
- Have the students make a field journal to use to take notes in from the lesson to use for biological monitoring a local stream

Start by asking the class if any of them have ever been in a body of water and noticed tiny insects in that water. Ask them what they thought about those critters when they saw them. You may get replies ranging from *gross* to *interesting*. Tell the class that in this lesson they are going to not only learn about those critters that live in the waters but also how they tell us the health of the Yukon River Watershed. When we read the health of water by using biological organisms (like those tiny insects we were talking about) that is called **biological monitoring.** Biological monitoring is carried out by collecting samples of biological beings and using them to decide the condition of a stream, and eventually the whole watershed.

In wadable streams (streams that can be easily walked across, with water no deeper than about thigh high), the three most common biological organisms studied are fish, algae, and macroinvertebrates. We will learn about and then monitor the **benthic** (means they live on the bottom) **macroinvertebrates** (means they are big enough to see with your eyes and do not have backbones). They are found in all types of running waters, from fast flowing mountain streams to slow moving muddy rivers. Macroinvertebrates found in the waters of our region are insects in their larval or nymph form. Most macroinvertebrates live most or part of their life cycle clinging to underwater rocks, logs, and vegetation. (USEPA Volunteer Stream Monitoring manual 1997: 47)

Monitoring biological organisms, especially benthic macroinvertebrates, will help provide a reading of the quality and health of a stream. These organisms show the effects of physical habitat changes**,** exposure to toxins or other contaminations, and the collective impacts of these problems over their life cycle. (Alaska Stream Team, 2004:7)

There are several reasons why macroinvertebrates are used for monitoring:

- There are typically found abundantly in most streams.
- They can be collected quickly and easily.
- They show collective impacts to a water system over an extended period of time.
- They provide a link in the food chain between primary producers and fish.
- They are a low-cost monitoring tool that anyone can use.

It is also a great way for anyone, including students and families, to get a "hands-on" science experiment. The results can be read and used to find out the activities on stream and **riparian** conditions (what is sitting on or taking place along or near the bank of a river). These results also provide an excellent way to pick out water bodies that might need a closer look due to a lack of signs of good health. (Alaska Stream Team, 2004:7)

The basic principle behind the study of macroinvertebrates is that some macroinvertebrates are more sensitive to pollution than others. Therefore, if a stream site contains organisms that can tolerate pollution and the more pollution sensitive organisms are missing, a pollution problem is likely. For example, stonefly nymphs are aquatic insects that are very sensitive to most pollutants and cannot survive if a stream's dissolved oxygen falls below a certain level. If it is discovered that no stoneflies exist in a stream that used to support them, a guess might be that dissolved oxygen has fallen to a point that keeps stoneflies from reproducing or has killed them outright. There are advantages and disadvantages of biological monitoring. The advantage is that it tells us very clearly when the stream ecosystem has a problem, or is "sick," because of pollution or habitat loss. It makes sense that a stream full of many kinds of crawling and swimming "critters" is healthier than one without much life. A stream showing more biodiversity shows us that it is a thriving habitat. The disadvantage is that it can be difficult to find the cause of why some creatures are present or absent. In this case, the absence of stoneflies might be due to low dissolved oxygen. Why is that? Is the stream under oxygenated because it flows too slowly? Or is it because pollutants in the stream are damaging water quality by using up the oxygen? The absence of stoneflies might also be due to other reasons like water temperatures are too high, habitat ruin such as excess sand or silt on the stream bottom that has ruined stonefly sheltering areas, or other conditions. Therefore a **biological assessment** (an evaluation of the health of a waterbody) should be added to the habitat and water quality readings in order to help explain the health of the stream, and eventually the watershed. (USEPA Volunteer Stream Monitoring manual 1997: 47-48)

Habitat, as it relates to the biological assessment, is defined as the "space occupied by living organisms." In a stream, the habitat for macroinvertebrates includes the rocks and sediments of the stream bottom, the plants in and around the stream, leaf litter and other decomposing organic material that falls into the stream, and submerged logs, sticks, and woody debris. Macroinvertebrates need the shelter and food this type of habitat provides and they tend to congregate in areas that provide the best shelter, the most food, and the most dissolved oxygen. A habitat survey examines these aspects and rates the stream according to their quality. (USEPA Volunteer Stream Monitoring manual 1997: 47-48)

Biological assessment results are typically reported as a portion of streams in a watershed that are rated very good, good, or poor. Biological assessments are also used as an educational tool in citizen/volunteer monitoring programs to provide basic information about watershed health. Results from biological assessments can be used to:

- Establish baseline characteristics
- Identify potential stressors to water quality
- Target areas for more intensive testing efforts
- Support land use planning and zoning management decisions
- Identify areas that warrant special protection, restoration, or rehabilitation (Alaska Stream Team 2004:8)

In relation to the Yukon River Watershed we will be learning about and monitoring three macroinvertebrates: (USEPA Volunteer Stream Monitoring manual 1997: 115)

1. **Stoneflies** *(Order: Plecoptera)*
2. **Mayflies** *(Order:Ephemeroptera)*
3. **Caddisflies** *(Order:Trichoptera)*

Stoneflies (Wikipedia)

Stoneflies have simple mouthparts with chewing mandibles or jaws, long, multi-segmented antennae, large compound eyes and two or three simple eyes. The legs are robust, with each ending in two claws. The abdomen is relatively soft, and may include remnants of nymphal gills even in the adult. Both nymphs and adults have long paired cerci (appendages) projecting from the tip of their abdomens.

Stoneflies are generally not strong fliers, and some species are entirely wingless. A few wingless species are exclusively aquatic from birth to death. Some may also be fully aquatic for their entire life, but can leave the water to travel.

The females lay hundreds or even thousands of eggs in a ball which they initially carry about on their abdomen, and later deposit into the water. The eggs typically take two to three weeks to hatch, but some species eggs can remain dormant throughout a dry season and hatching only when conditions are suitable.

The nymphs are aquatic and live in the benthic zone of well-oxygenated lakes and streams. The nymphs resemble wingless adults, but often have external gills, which may be present on almost any part of the body. In addition, they can also breathe through the general body surface, and some even lack gills altogether. Most species are herbivorous (they eat plant material only) as nymphs, feeding on submerged leaves and benthic algae, but many are hunters of other aquatic arthropods.

The insects remain in the nymphal form for one to four years, depending on species, and undergo anything from 12 to 33 molts before emerging and becoming terrestrial as adults. The adults generally only survive for a few weeks, and emerge only during specific times of the year. Some do not feed at all, but those that do are herbivorous.

Stoneflies display wings or wing Pads, two tail filaments, and do not have abdominal gills.

Mayflies (Wikipedia)

Mayflies are aquatic insects whose immature stage (called "naiad" or, "nymph") usually lasts one year in freshwater. The adults live a short amount of time, from a few minutes to a few days depending on the species. Eggs are laid on the surface of lakes or streams, and sink to the bottom. Nymphs molt 20 to 30 times over a period of a few months up to a year, depending on the species. The nymphs live primarily in streams under rocks, decaying vegetation, or in the sediment. Few species live in lakes; however they are among the most common of the species. Most species feed on algae or diatoms, but there are a few predatory species. The nymph stage may last from several months to several years, with a number of molts along the way. Most mayfly nymphs are distinctive in having seven pairs of gills on the dorsum (upper side) of the abdomen. In addition, most possess three long cerci or tails at the end of their bodies. Some species have only two tails. In the last aquatic stage, dark wing pads are visible. Mayflies are unique among insects in that they molt one more time after growing functional wings. This last-but-one winged stage usually lives a very short time, often a matter of hours. Mayflies in this stage are a favorite food of many fish, and many fishing flies are modeled to resemble them.

Mayflies have wings or wing pads, two or three tail filaments, and have abdominal gills.

Caddisflies (Wikipedia)

Caddisflies are closely related to moths and butterflies. Caddisflies have aquatic larvae and are found in a wide variety of habitats such as streams, rivers, lakes, ponds, spring seeps, and temporary waters. The larvae of many species make protective cases of silk decorated with gravel, sand, twigs or other debris.

Caddisfly species can be found in all feeding guilds in stream habitats, with some species being predators, leaf shredders, algal grazers, and collectors of particles from the water column and the bottom.

Caddisfly pupate in a cocoon spun from silk. Caddisflies which build the portable cases attach their case to some underwater object, seal the front and back against predation but still allow water flow, and grow within it. Once fully developed, most caddisflies cut through their cases with a special pair of mandibles, swim up to the water surface, cast off skin and their gills and mandibles, and emerge as fully formed adults. Many of them are able to fly immediately after breaking from their pupal skin.

The adult stage of caddisflies, in most cases, is very short-lived, usually only 1–2 weeks, but can sometimes last for 2 months. Most adults are non-feeding and are equipped mainly to mate. Once mated, the female caddisfly will often lay eggs (enclosed in a gelatinous mass) by attaching them above or below the water surface. Eggs hatch in as little as three weeks.

Caddisflies complete their life cycles in a single year. The general temperate-zone lifecycle pattern is one of larval feeding and growth in autumn, winter, and spring, with adults coming forth between late spring and early fall, although the adult activity of a few species peaks in the winter. Larvae are active in very cold water and can frequently be observed feeding under ice.

Caddisflies have six jointed legs, have no lateral filaments, and some have branched gills the bottom side of their abdomen while other display no branched gills.

Where to Look for Good Macroinvertebrate Collection Sites

The first step to finding a good macroinvertebrate collection site is to locate wadable streams in the area. The next step is knowing the type of habitats of benthic macroinvertebrates and their names. Typically there are four areas of the stream to sample where macroinvertebrates live. The following lists the predominant habitat types:

• **Riffle/Cobble** — fist-sized rocks on the bottom of a fast flowing stream.

• **Undercut banks/roots or vegetated bank margins** — overhanging bank vegetation or submerged roots attached to the stream banks.

• **Snags** — sticks or logs submerged underwater that are not recent downfall.

• **Aquatic vegetation beds** — areas of submerged vegetation. (Alaska Stream Team 2004: 13)

Varying flows and depths also create a variety of habitats for macroinvertebrates. **Pools** are deep with slow water. **Riffles** are shallow with fast, turbulent water running over rocks. **Runs** are deep with fast water and little or no turbulence.

At the Macroinvertebrate Collection Site

A word of caution: Do not sample when the water is running high and fast. It may be dangerous and strong currents dislocate benthic organisms. Your results may not accurately reflect the quality of your site!

A team of samplers outfitted in proper footwear, long rubber gloves, and the D-frame net will collect a **composite sample** from five separate locations of the predominant habitats identified prior during a stream walk. (If riffle/cobble is your predominant habitat type and snag is your second most predominant habitat type, then you will collect three samples from the riffle/cobble habitat and two from snag habitat for a total of five.) A **jab** type of motion is used to collect the sample. The entire composite sample from the five sample locations is emptied into the bucket and is processed as one sample to represent your stream reach. (If you have collected a lot of debris, the net may need to be cleaned out in between the 5 samples.) (Alaska Stream Team 2004: 15)

The following describes how each habitat type is sampled using a D-frame net.

• **Riffle/Cobble**: Place the net in the stream with the water flowing into the net. One person should hold the net firmly in place on the stream bottom while the other person stands in front of the net. The person in front of the net dislodges the organisms from the rocks and substrate by picking up and rubbing the large rocks and moving these to the side and then stirring the smaller substrate underneath. Disturb the area 18 inches in front of the net and about 1.5 inches into the Stream bed for approximately 3 minutes.

• **Snags**: Place the section of submerged wood into or in front of the net and rub off organisms from about 18 inches of the material for about 2 minutes.

• **Undercut Banks**: Approach the bank from downstream and jab the net vigorously along about 18 inches of the bank with an upward motion to dislodge any organisms. The entire jab motion should occur underwater. Approximately 5 passes should be used to complete this jab.

• **Aquatic Vegetation Beds**: Jab vigorously along about 18 inches of any vegetative beds with an upward motion of the net against or through the plant bed. This entire motion should occur underwater. Approximately 5 passes should be used to complete this jab. For younger groups, you may choose to use the kick net for sample collection. It is recommended that one sample be taken from two different riffle/cobble areas, preferably from the middle and edge of the stream. For variation, the kick net can be used to sample other habitats, such as the margins of weed-beds and undercut banks. You will find the community of bugs in each of these habitats may be quite different than the other areas in the stream. (Alaska Stream Team 2004: 15-16)

Sample Processing

Samples should be processed in the field at the end of the sample collection. Some may contain a lot of leaves and rocks. A stir-and-pour technique is used to separate the insects and organic matter from the inorganic sand and rocks. After the entire composite sample is emptied into the bucket, gently stir it until the leaves and organic matter are suspended in the water. The floating organic matter can be visually inspected for insects and then placed back into the stream.

Sorting, Identifying, and Counting

Begin by removing the remaining leaves, twigs, and rocks from your sample. Look closely for bugs that are on stems of leaves, on twigs, and in cracks of rocks. Pick out all of the different types of organisms in the sample using the hand lens and forceps and transfer them to the ice cube trays. Group bugs by looking at the body shape and number of legs and tails. You may have several different types of each of the mayflies, caddisflies, and stoneflies. To assist in sorting into groups, you may also want to look carefully at the type of movement the bugs make. Many of these organisms are small and quick! An eyedropper or pipette may be useful to catch very small organisms. If you are having trouble catching some of the faster insects, try pouring some extra water into the pan.

Use a hand lens to separate the specimens by their physical differences. Again, the three most sensitive **orders** include mayflies (**E**phemeroptera), stoneflies (**P**lecoptera), and caddisflies (**T**richoptera). These are commonly referred to as **EPT taxa**. Each EPT group contains many species. These three groups are often considered the **indicator species** of stream health. Also separate other organisms into groups using physical characteristics (blackflies, worms, leeches, etc.) (Alaska Stream Team 2004: 16-17)

Use the following general guidelines to differentiate the three main groups:

- **Mayfly nymphs** wiggle back and forth when they move and have either two or three **cerci** or "tails." They also have distinct gills on the lower abdomen.
- **Stonefly nymphs** travel in a straight line, have only two cerci, have a smaller "neck" than mayflies, and generally have longer antennae.
- **Caddisfly larvae** are either in their little tube-shaped houses of leaves, twigs, or stone or they look like worms with heads and six jointed legs.

If you have all three types of EPT bugs at your site, you probably have a very healthy site! It is also important to note the other organisms you discover in your sample.

Activity:

If able, take the class out to find wadable stream(s) near your community and have the students identify whether they are wadable or not. Once the class has selected the wadable stream(s) that they are going to sample for macroinvertebrates, have them write in their field journal their prediction of the health of the stream(s). They can categorize the health ranging from very poor health to very good health. Have students explain their predictions.

From the habitat types mentioned above (Riffle/Cobble, Snag, Undercut Banks, Aquatic Vegetation Beds), have students select the areas that are the most common in the stream(s) that they identified as wadable. Next you will be collecting a sample that is composed of “kicks or jabs” from these habitats. (For example, depending upon the stream you may collect 3 from the riffle/cobble and 2 from snag habitat in one stream and 3 from undercut banks and 2 from riffle/cobble in another stream.)

Next have the students take jab samples in the selected habitat types using nets. Next they will empty the composite sample into a bucket. If needed, have students gently stir until organic debris is suspended in the water. The floating organic matter can be visually inspected for insects and then placed back into the stream.

Then the students should begin to remove the remaining leaves, twigs, and rocks from the sample. Have them look closely for bugs that are on stems of leaves, on twigs, and in cracks of rocks. They should pick out all of the different types of organisms in the sample using the hand lens and forceps and transfer them to trays and group bugs by looking at the body shape and number of legs and tails.

Have students write in their field journal the types and number of species found at each sample site, just like a biologist would. The students should write the total number of the EPT insects found. After the findings, lead the class in a discussion in whether the stream(s) shows signs of good health or not. See which students had accurate predictions.

Additional Activities

-Have the class to a trash pick-up along the stream(s) that they sampled. Even if the stream(s) showed signs of good health, you should stress why it's important that it keeps a healthy status.

-To see EPT insects up close and learn more about them have students check out the following website: http://macroinvertebrates.org/#/ephemeroptera/heptageniidae/maccaffertium/dorsal.

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Sources for this curriculum:
This curriculum was adapted from the Environmental Preservation Lifeways Curriculum that was developed by the Telida Village Council and the Indian General Assistance Program (IGAP). Adaptation came from What Bugs Tell You About Your Water Quality lesson that is part of the Water Quality Science and Monitoring education. This curriculum and more can be found at: http://ukpreservation.com/environmental-curriculum/ .

This curriculum was adapted for the Yukon River Watershed region and by the Yukon River Inter-Tribal Watershed Council.

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Additional Resources:
The Yukon River Inter-Tribal Watershed Council has a vast number of resources available online at www.yritwc.org. For more information, call (907) 258-3337.