October 3, 2006

To: Recipients of *River Fieldwork Guide for Teachers*, a publication created for VINS' Environmental Citizenship Program

RE: Acknowledgement Omissions

It has come to our attention that two contributors to our *River Fieldwork Guide for Teachers* were either not mentioned or credited incorrectly in the final publication of the book.

- Jurij Homziak, Extension Assistant Professor for UVM's Watershed Alliance and a specialist in the chemistry, physics, and earth science, contributed his work to the *Guide's* chapter on river chemistry.
- Caitrin Noel, Outreach and Education Coordinator for the Alliance, specializes in stream ecology. Her expertise in that area contributed to the *Guide's* emphasis on life sciences and human and watershed interaction.

We deeply regret these two omissions to our work. The *River Fieldwork Guide for Teachers* could not have been developed with the expertise of Mr. Homziak and Ms. Noel.

Thank you for your attention to this matter.

Teresa Mitchell
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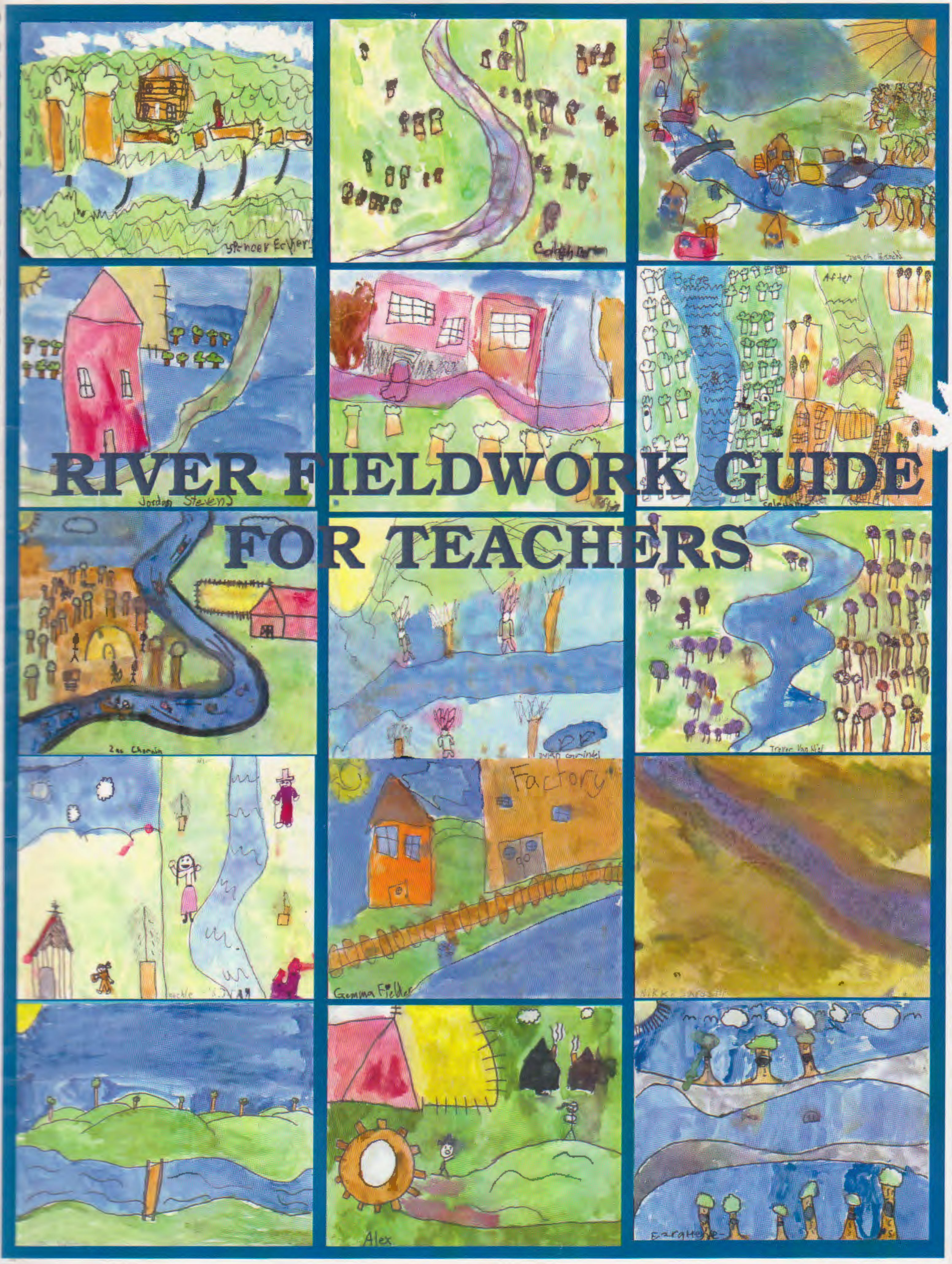
RIVER FIELDWORK GUIDE FOR TEACHERS



RIVER FIELDWORK GUIDE
For Teachers

A unit of
Environmental Citizenship:
Learning to Make Informed Decisions

June 2006

June 2006 Edition *"River Fieldwork Guide for Teachers"* developed by Kimberly Jensen and edited by Mike Muller. Contributing authors were Caitrin Noel, Jenna Guarino, Kimberly Jensen, Lori Barg and Matt Bratner. Special thanks to Kari Dolan. Illustrations were produced by Susan Sawyer. Funding was made possible by generous grants from The Wellborn Ecology Fund of the Upper Valley Community Foundation dedicated to increasing awareness of environmental and ecological issues in the Upper Valley of the Connecticut River.

What is Environmental Citizenship?

Environmental Citizenship (EC) is an educational program for middle school students focused on balancing the needs of humans and wildlife through informed decisions. Students learn about natural systems, conduct outdoor scientific investigations, and contribute to community environmental health through educational activities and citizenship projects.

The Five EC Units

- Atlantic Salmon: A Watershed-Wide View
- Trout: A Watershed-Wide View
- Bobcats: Predators in a Changing Landscape
- Vernal Pools: Life in Temporary Ponds
- Thrushes: Migrant Songbirds of the Forest

Note: Each unit has an accompanying TEACHING KIT that is available from VINS.

June 2006 Edition
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VI. The River's Biological Community

The physical and chemical components of a river set the stage for its biological community – the plants, animals, and other organisms that live together in an ecosystem. These living organisms, in turn, interact with the environment, altering its physical and chemical conditions. Even dead organisms influence the physics and chemistry of the river.

Examples of the effects of organisms (living and dead) on physical and chemical characteristics in a river:

1. Algae growing on a rock remove certain minerals from the rock, causing slow erosion of the rock over time.
2. Bacteria decompose human sewage leaking into the river from a leach field, consuming lots of the river's limited supply of dissolved oxygen.
3. A dead tree falls into a stream, blocking its flow and slowing down the water, which causes the water to release its load of sediments onto the streambed.
4. As vegetation grows up along a stream bank, it shades the river more and more over time, decreasing the water's temperature.

Each set of conditions – physical, chemical, and biological – interacts with, and influences, the other two. This dynamic interplay creates the habitats necessary for aquatic life to flourish in rivers. The result is a complex assemblage of biological communities.

Despite the river's complexities, a savvy river reader can use aquatic organisms as indicators of a river's health. In this chapter, we will focus on a certain group of indicator organisms known as *benthic macroinvertebrates* that you can easily sample with your students. The parts of this term can be defined like this:

- Benthic – attached to the streambed or any solid object in the river (such as a log)
- Macro – big enough to see with the unaided eye (as opposed to micro, which requires magnification)
- Invertebrate – lacking a backbone

The majority of benthic macroinvertebrates (BMIs) in a river are aquatic insects, but this group also includes aquatic snails, worms, crayfish, clams, and other organisms that fit the description above. In order to survive in water, a BMI must possess a respiration system that allows it to capture oxygen, a strategy for acquiring food, behavioral traits that allow it to perform the tasks essential to its life, and certain mechanisms for maintaining proper salt concentrations within its body.

Only about 10% of all insects are aquatic, but aquatic insects are the biggest group of BMIs in a river, so they are a significant biological component of this ecosystem. In adulthood, most BMIs are terrestrial, except for a small number of species that live in water throughout their entire life cycle. The terrestrial adults go back to the river to lay their eggs, and their young, referred to as either larvae or nymphs (depending on which process of metamorphosis they undergo[2]), live an aquatic life. Most water time is spent in the juvenile (immature) stages, and most terrestrial time is spent in adulthood. Each transition to a new life stage is facilitated by special adaptations, but once they settle into the new stage they are restricted to either air or water. However, there are some aquatic insects that can leave the river at will in order to escape bad conditions or disperse to other habitats. For example, the water boatman lives its whole life in water, yet it breathes air with lungs and possesses wings as an adult. If conditions within a river become undesirable, the water boatman can fly off to find a better situation elsewhere.

In this chapter, you will learn something about the food sources that are important to benthic macroinvertebrates, how they obtain their food, and how they survive the challenging conditions found in a typical river system. You will be introduced to a set of protocols (scientific procedures) that will guide you through the collection of data on BMIs in your river and help you understand what this information tells you. This process, when applied and practiced in an actual river, will allow you and your students to measure your river's health using biological indicators.

Before you and your river readers venture out to collect organisms, it is important to understand a concept called *The River Continuum.* This concept will help you predict the organisms you will find and where you will find them in your river.

The River Continuum

The aquatic organisms in a typical river and the relationships between them tend to be distinct in various parts of that river. This is because the physical and chemical factors, and therefore the available habitats for organisms, change in a predictable way as the river system flows along. This River Continuum Concept can tell you something about the kinds of river characteristics that you can expect to find in a particular location along the river system and, therefore, about the biological community that might live there.

The following section describes the characteristics that are typical of a northeastern river. Although there are many exceptions, this profile helps us to understand how rivers change as they flow along, and therefore how the biological communities change from headwaters, through the tributaries, and down to the mainstem.

[2] *Larvae* go through "complete" metamorphosis, which progresses through 4 stages (egg, larva, pupa, and adult). *Nymphs* go through "incomplete" or "gradual" metamorphosis, which progresses through 3 stages (egg, nymph, and adult).

Physical and Chemical Characteristics Along the River Continuum

Generally, the River Continuum Concept describes 3 distinct regions within a river system: an upper reach, a mid-reach, and a lower reach. The upper reach is found at the highest elevations of the watershed, where precipitation gathers into tiny streams which form the headwaters of the watershed. These primary streams of the river system are called *first order streams* and are assigned the number 1. As the water flows downhill, these first order streams flow together into *second order streams* which come together into *third order streams*, and so on until the entire river system empties into another body of water, either another river, a still water body (pond or lake), or the ocean. Flowing waters of orders 1 through 3 are considered to be in the upper reach of the river system.

The upper reach tends to be characterized by:

- Steep gradient (slope)
- Moderate to fast water velocity, often with riffles and falls
- Rocky streambed
- Narrow channels that are heavily shaded by trees and other vegetation
- Cold water that is high in dissolved oxygen
- Poor in nutrients and low in major ions[3]
- Low diversity of habitats (because of fairly uniform physical and chemical conditions)

The mid-reach is found at the mid-elevations of the watershed and includes streams of orders 4 and 5. (Remember that a 4th order stream is fed by two 3rd order streams, 3rd order streams are fed by two 2nd order streams, and a 2nd order stream is fed by two 1st order streams.) Streams in this middle section of the watershed are the tributaries of the mainstem of the river (see below).

The mid-reach tends to be characterized by:

- Moderate to low gradient
- Water velocity varies from almost still (in pools) to fast (in riffles and rapids)
- Streambed with rubble and gravel (see Habitat Assessment Information below)
- Channels of moderate width whose edges can be shaded (if undisturbed), partially shaded (if human activity has removed some of the riparian vegetation), or completely exposed to the sun (if human activity has removed all of the riparian vegetation).

[3] Ions are atoms or small molecules that are electrically charged, either positively or negatively. In a typical river, they include sodium, potassium, calcium, magnesium, chlorine, bicarbonate, silicate, and sulfate.

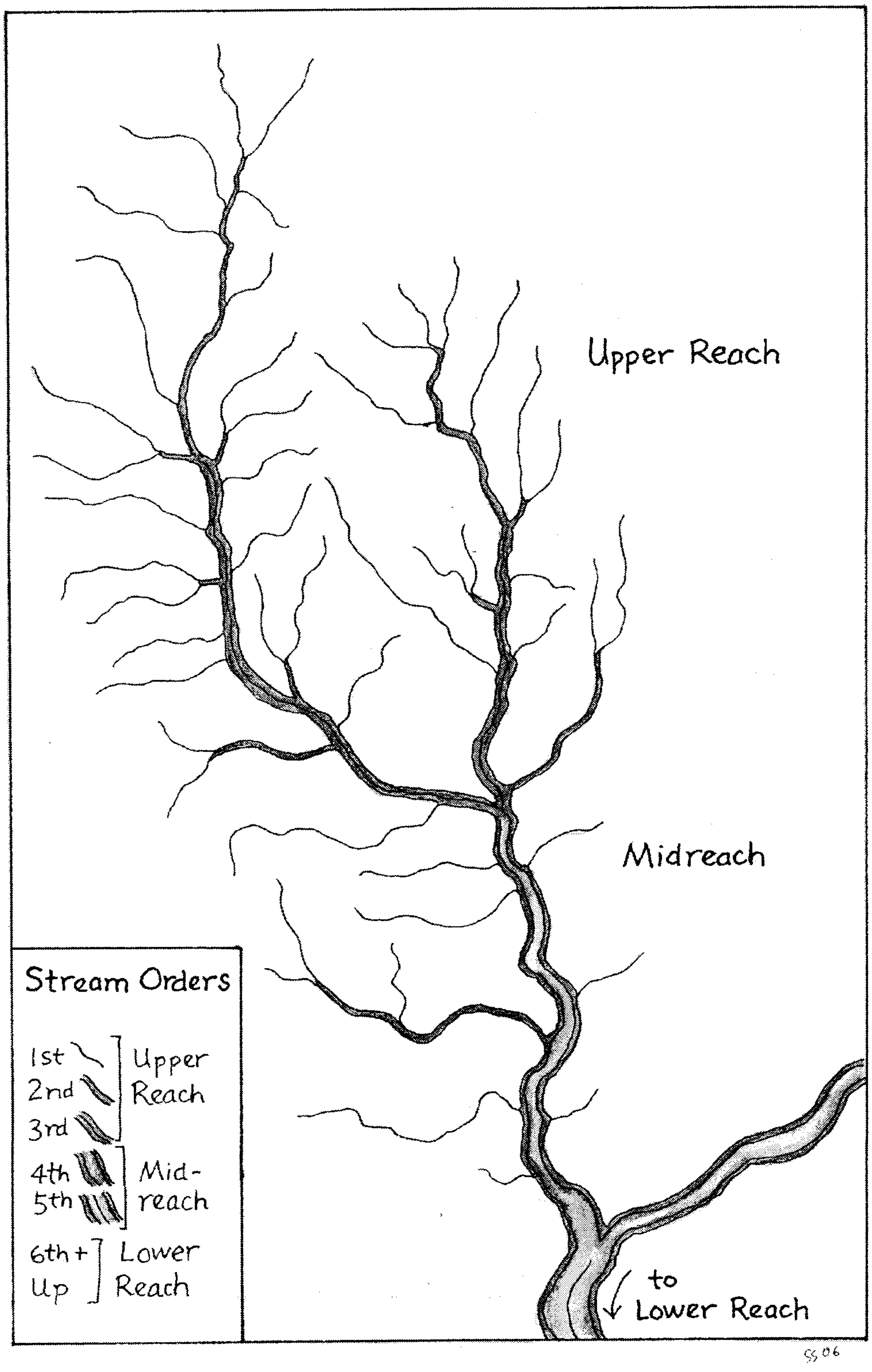
- Moderately warm water with varying amounts of dissolved oxygen
- Rich in nutrients and a high level of major ions
- High diversity of habitats (because of a variety of physical and chemical conditions)

Finally, the lower reach is found in the valley, where all flowing waters in the basin gather together into a large river, generally of 6^{th} order or above. This is the mainstem of the river system.

The lower reach tends to be characterized by:

- Low gradient to relatively flat
- Moderately or very slow water
- Sandy and/or silty streambed
- Wide channels, often with little or no bank vegetation due to human activity, in which the water is exposed to the sun
- Relatively warm water with low dissolved oxygen
- High level of nutrients and major ions
- Low diversity of habitats (because of fairly uniform physical and chemical conditions)

STREAM ORDER IN A WATERSHED



Biological Characteristics along the River Continuum

Note: We recommend that you obtain a guide to aquatic invertebrates for use in your biological studies of rivers. An excellent resource is A Guide to Common Freshwater Invertebrates of North America by J. Reese Voshell, Jr. This and other useful materials are cited in the Resources section of this manual.

The biological community of a typical river includes the obvious players, such as fish, amphibians, and aquatic insects. But it also includes lesser-known inhabitants that are equally essential to river health, such as worms, bacteria, and algae. In addition to living organisms, dead organisms are crucial to a river's biology by recycling nutrients and providing food sources for living organisms. All organisms, both living and dead, play a role in the river's food web, which represents the intersecting avenues along which energy is captured and transferred within this ecosystem to promote the growth and proper functioning of its organisms.

When you use benthic macroinvertebrates as indicators of river health, it is important to know where you are along the river's continuum. As we have seen, physical and chemical characteristics change as the river flows along, and therefore habitats change as well. At each spot along a river, there is a community of aquatic organisms that are able to make a living there.

Scientists have investigated healthy ("reference") rivers in the northeastern U.S. and described the biological communities that exist in distinct habitats along the river continuum. These descriptions will guide you as you explore your own river's state of health. The field techniques in this manual help you to compare *what you would expect to find* in your river with *what you actually find.* If you find what you would expect to find, given your location along the river continuum, then your river is considered healthy. If you find a biological community that is different than the reference community, then you may have uncovered a problem in your river. In many cases, the kinds of organisms you find can help you determine the nature of that problem.

In order to use benthic macroinvertebrates as indicators, you need to be able to identify them and understand how they obtain oxygen, what they eat, and how they behave. Each of these points is addressed below.

Obtaining Oxygen

Oxygen is required for cellular respiration in most aquatic animals, just as it is required in land-dwelling (terrestrial) animals. Oxygen dissolves into water under certain conditions. The levels of dissolved oxygen (DO) in water are influenced by several factors:

- Movement – water that is moving mixes in air containing oxygen;
- Temperature – cold water holds more oxygen than warm water;
- Aquatic plants – they release DO into the water as they grow; but when they die, the microscopic organisms (e.g., bacteria) that decompose them require DO.
- Aquatic animals – they take DO out of the water when they respire, so their type and abundance can influence DO levels;

- Organic pollutants – cow manure, human sewage, and other organic pollutants can cause a drop in DO because the microscopic organisms that decompose them require DO.

A cool, free-flowing river with well-vegetated riparian zones and a healthy in-stream population of green plants produces high levels of dissolved oxygen, which supports a great diversity of aquatic invertebrates. On the other hand, a river whose banks are devoid of vegetation and therefore exposed to the warming effects of the sun, with a slow current and few aquatic plants, is oxygen-poor; it may support just a few species that can tolerate impoverished conditions. If this latter river is then subject to an organic pollutant such as manure-filled runoff from a farm field, oxygen levels fall even further and diversity drops ever lower. At a certain point of oxygen depletion, very few species can survive. (Note: While running and still water bodies have a lot in common, they are different when it comes to dissolved oxygen levels and their effects on water quality. Standing, warm waters, like ponds, often have low oxygen levels but they can be healthy systems.)

Even in healthy rivers, oxygen dissolves into the water in only tiny quantities, which are always in flux. Therefore, oxygen availability is often a limiting factor for aquatic organisms, especially "sensitive" organisms that require high levels for survival. These sensitive aquatic invertebrates are good indicators of water quality because high water quality is correlated with high dissolved oxygen levels. Aquatic invertebrates that require only low levels of dissolved oxygen or are able to access atmospheric air are tolerant of ("insensitive" to) poor water quality.

One fifth of atmospheric air – 21% or 21 parts per hundred - is comprised of oxygen, which remains in constant supply. In contrast, dissolved oxygen levels in water are measured in parts per *million*. For a comparison, look at these figures:

Atmospheric oxygen (from air): always 21%	= 0.210000
Dissolved oxygen (in water): variable; if it's 6 parts per million	= 0.000006

When using BMIs as indicators of river health, it is important to know how they obtain their oxygen and to what degree they are sensitive to decreases in dissolved oxygen.

Air Breathers

Some aquatic insects have sidestepped the need to capture the tiny amounts of dissolved oxygen in water by taking it directly from the air above. This requires that they have continual or occasional contact with the air, which influences how they make their living.

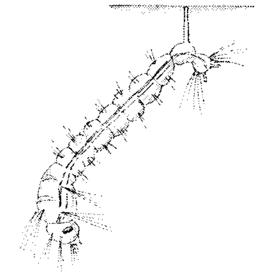


Figure 8: Mosquito Larva

Invertebrates that reside on the surface of the water have ready access to the oxygen in air. Like terrestrial insects, they have paired spiracles - openings into the internal respiratory system – along the thorax and abdomen. The mosquito larva, which hangs

upside-down from the underside of the water's surface, also takes in atmospheric oxygen, but it lacks spiracles. Instead, it has a tube or siphon on the end of its abdomen that pierces the surface film to access the air while also attaching it in place. If the mosquito larva is disturbed, it "holds its
breath" and wriggles down into the water to escape. Once the disturbance has passed, it floats back up to reconnect with the surface film and its supply of oxygen.

Some aquatic insects that spend most of their time underwater also rely on atmospheric oxygen. The water scorpion has a breathing tube at the end of its abdomen, and occasionally it floats up to the surface, hind end tilted up, to take in a breath of air.

Other aquatic insects use the "scuba diving" method of using atmospheric oxygen; they visit the surface to capture a bubble of air, which they hold next to their bodies and from which they take oxygen as they swim underwater. As the oxygen in the bubble gets depleted, dissolved oxygen from the water diffuses into it, thereby replenishing the bubble's oxygen supply. If dissolved oxygen levels in the water are high, the bubble can take in lots of dissolved oxygen from the surrounding water and the insect can stay submerged for a long period of time. If the water is oxygen-poor, the insect must surface more often. Eventually, most insects with such "physical gills" must come to the surface for fresh oxygen.

The water boatman and backswimmer are two classic scuba diving insects that use bubbles in this way. The water boatman holds its bubble under the wings on its back. Look for the shiny, silvery bubble extending out from under the ends of the wings at the "tail" end. The paddling action of its hind legs while swimming circulates water over this physical gill, which increases the bubble's contact with dissolved oxygen in the water. The backswimmer's "belly" has two troughs that hold air. It also holds air under its wings and between its head and thorax. Watch both the water boatman and the backswimmer float up to the surface, back end first, to refresh their bubbles.

Water Breathers

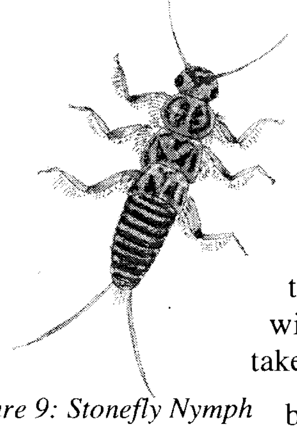


Figure 9: Stonefly Nymph

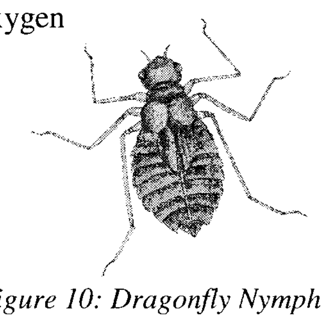


Figure 10: Dragonfly Nymph

"Water breathers" that take dissolved oxygen from the water face the continual challenge of finding enough oxygen to meet their needs. Some aquatic insects have evolved specialized structures, called gills that allow them to access the dissolved oxygen in water. Gills can take many forms, such as the hair-like tufts that surround the base of the stonefly's legs (they look like "hairy armpits"), or the three paddle-like gills that are found at the end of the damselfly's abdomen. Dragonfly nymphs have gills within the anus at the end of the abdomen, where they take in water to tap its dissolved oxygen. As an added bonus, dragonfly nymphs are able to expel water rapidly from the anus, which propels them forward in sudden bursts of movement. You can watch a dragonfly employ this method of "jet propulsion," which allows this predator to catch unsuspecting invertebrates and, in turn, escape other critters that want to eat the dragonfly.

Some small and immature aquatic insects have such meager oxygen demands that they don't require any fancy oxygen equipment. From their location on or within the bottom of the stream, they simply draw dissolved oxygen directly through their exoskeletons in a process called cutaneous respiration.

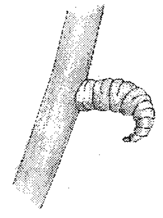


Figure 11: Leaf Beetle Larvae

<u>Plant Drillers</u>

Some aquatic fly larvae and pupae require neither access to the air nor access to dissolved oxygen in the water. From their habitat down in the mud, they obtain their oxygen by drilling into aquatic plants and tapping the oxygen produced within them.

Food Sources for Benthic Macroinvertebrates

In most ecosystems, green plants make up the primary food source. In a river, the amount of available sunlight determines whether the primary food source is live green plants or decomposing plant matter from the terrestrial environment. The upper reach of the river continuum receives very little sunlight because the streambed is narrow and tends to be deeply shaded by streambank (riparian) vegetation. In addition, the water contains few nutrients to nourish plants. Therefore, few green plants grow within the stream itself. Much of the available food in the upper reach comes from terrestrial sources along the stream. Riparian vegetation drops plant parts into the river, such as leaves and branches. This organic material, along with terrestrial insects that jump or fall into the river, dead animals, and animal feces, provide essential raw materials for the organisms here. If this material is larger than 1 millimeter in size, it is called *coarse particulate organic matter (**CPOM**)*. CPOM is an essential food source for certain kinds of organisms, which tear it into smaller pieces or gather it from the streambed. As CPOM is eaten and excreted in waste products, it is further broken down into smaller pieces. Organic material that is 0.0005 to 1.0 millimeter in size is called *fine particulate organic matter (**FPOM**)*. Certain organisms have adaptations that allow them to capture and eat this smaller material.

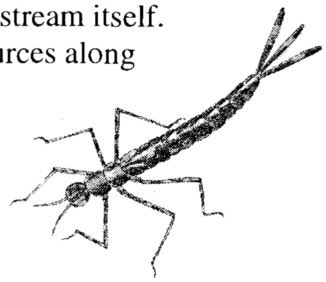


Figure 12: Damselfly Larvae

In the mid-reach, CPOM is available from organic matter that falls into the river (such as leaves) and it is broken down into FPOM, as in the upper reach. But another food source becomes important here - plants, or *autotrophs,* which are organisms that make their own food from sunlight and non-living materials through a process called photosynthesis. Several conditions create an environment conducive to photosynthesis in this area of the river. The decomposition of organic matter upstream as well as within this region releases nutrients that fertilize these waters. Some parts of the streambed are exposed to sunlight. The current tends to be slower, which allows plants to attach and grow. A tiny "forest" of photosynthesizing algae and bacteria called ***periphyton*** colonizes most surfaces that receive sunlight (rocks, soft sediments, other plants) in the river and rooted plants grow along the stream's calmer edges. Numerous herbivorous invertebrates graze the plants or suck juices from them. The variable conditions found in the mid-reach create a diversity of habitats that support a rich community of organisms.

In the lower reach, the river tends to be flat, slow, and deep. Plants root in the fine sediments of the streambed and find abundant sunlight where riparian vegetation is minimal. Algae grow on any rocks that are close enough to the surface to allow light to penetrate the water. Tiny, free-floating plants called ***phytoplankton*** make a living within the water column. Because conditions here are fairly uniform, macroinvertebrate diversity tends to be low. Here we see macro-invertebrates that filter material out of the water column and eat the plants growing in this habitat.

Of course, predatory macroinvertebrates are found all along the river continuum wherever there are prey to be eaten. Various other macroinvertebrates with feeding styles adapted to their habitats also live in our rivers, as we will see below.

Functional Feeding Groups

Aquatic macroinvertebrates can be grouped into **functional feeding groups** according to what they eat and how they are adapted to eat it. Feeding adaptations include specially designed body parts and behaviors. Functional feeding groups reflect the food sources that are available in a river. In the headwaters region, which offers lots of CPOM, you find organisms that are designed to shred this organic material into smaller pieces. In the mainstem, which carries small suspended material (FPOM), lots of filtering organisms make a living. At any particular place along a river system, you can expect to find certain communities of functional feeding groups depending on what is available for food.

The presence of all functional feeding groups within a river system indicates a variety of food sources, which points to a diverse, healthy system. If one group dominates, there may be an imbalance in the river. For instance, decomposing sewage in the river may cause filtering organisms to increase. In order to know what kinds of functional feeding groups you might expect to find at your sampling site, you need to know where you are along the river continuum and to think about the food sources that are available there. Are the invertebrates that you find the ones that are typical for your spot in the river continuum? If not, further exploration is warranted to undercover potential stresses to the river.

Functional feeding groups in a river:

1. <u>Shredders</u> chew and shred organic material that is bigger than 1 millimeter (CPOM), such as leaves and branches from riparian vegetation or parts of aquatic plants. Often, these organisms obtain most of their nutrition not from the plant part itself but from the community of fungi and bacteria that colonize this material to decompose it. You

can think of the leaf as the "cracker" and the decomposers as the "peanut butter" along its surface.

2. Collectors acquire fine food particles in the river that are usually smaller than 1 millimeter in size (FPOM). *Collector-filterers* strain food from the flowing water. Black fly larvae have fans of hairs on the top of their heads that catch goodies floating by. Net spinning caddisfly larvae produce silk and weave a net that strains particles being carried along. *Collector-gatherers* eat the fine materials that settle out of the water. They either occupy the bottom and eat the sediments on the top layer (non-biting midges) or burrow through the sediments swallowing material as they go (aquatic earthworms).

3. Grazers or scrapers harvest the periphyton (tiny plants and bacteria) that grows on solid objects, like rocks, in the river. Organisms in this group include snails, flatheaded mayflies, and water pennies.

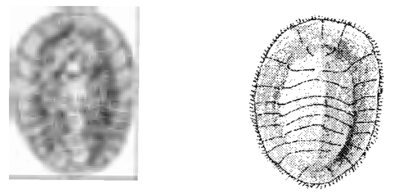


Figure 13: Water Penny

4. Piercers have narrow, elongated mouthparts that pierce and suck. *Piercer-herbivores*, of which there are just a few species in aquatic systems, pierce and then suck aquatic plants. *Piercer-predators*, on the other hand, are very numerous in rivers, ponds, and wetlands. They stalk their prey, capture it, and many pump digestive juices into their prey to dissolve their internal tissues and then suck out the fluids. Water scorpions and predaceous diving beetle larvae are examples.

5. Engulfer-predators catch and eat an entire organism or tear it into smaller pieces to eat. They have adaptations for capturing their prey and usually possess large jaws and tooth-like structures. The common stonefly larva is such an organism.

Behavioral Groups

Aquatic macroinvertebrates can also be grouped according to the ways in which they perform the tasks that help them meet their needs. Behaviors can be understood by observing the movements of living organisms and by looking at the shape of the body and its individual parts. Behaviors reflect adaptations for:

- moving
- holding on in a fast current
- finding and capturing food
- securing shelter from harsh environmental conditions
- hiding from predators

Observing physical adaptations that reflect behaviors is an important step in identifying BMIs and understanding the conditions they require for survival. Scientific guides often describe the following sets of behaviors, which are frequently found in particular regions of a river. Please note that many organisms exhibit more than one kind of behavior since they must respond to varying physical and chemical conditions and the availability of food, so the following information describes general characteristics only.

Benthos is the term for benthic organisms that live attached to substrates (e.g., rock, log) or buried within soft substrates (e.g., sand, mud). They rely on the flowing river to deliver their food and oxygen to them. This group includes:

1. Clingers hold on tight in strong currents and generally stay put. Their adaptations may include:

    a. grasping claws at the ends of the tarsus (legs) or at the anus (e.g., some adult riffle beetles)
    b. hooks at the end of the abdomen (e.g., some midge larvae)
    c. suction discs on the abdomen (e.g., the black fly larva suctions its end onto a hard surface and "stands" upright in the current; the entire outside margin of the water penny acts like a suction disc)
    d. glue made by the organism (i.e., caddisfly larvae that uses its glue to build a "house" which it adheres to a rock)
    e. streamlined body shape that allows water to flow over the organism and force it closer to the substrate (e.g., some mayfly larvae)

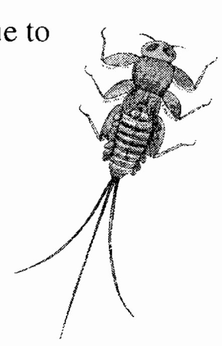


Figure 14: Flathead Mayfly Nymph

2. Sprawlers crawl around the surfaces of rocks, sediments, leaf packs, etc., in fast and slow waters. Many species live on the underside of rocks – watch them skitter around when you lift their rock out of the water. This group includes stonefly nymphs and some mayfly nymphs.

3. Climbers are usually found in slower waters among aquatic plant stems, root systems, algae, and mosses. While many remain relatively still among the plants, others swim from one surface to another. A very common climber in aquatic vegetation along the bank is the damselfly nymph.

4. Burrowers dig down into soft sediments in slow stretches of a river, such as pools and along quiet banks. Some excavate actual tubes or burrows. Some have physical adaptations for digging, such as wide forelegs or tusks in the head. A well-known example is the burrowing mayfly larva, which can often be found by scooping out a hunk of fine sediment and watching carefully for squirming insects.

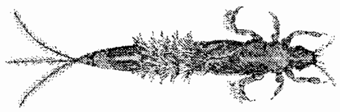


Figure 15: Burrowing Mayfly Nymph

Plankton are organisms that float or are suspended within the water and do not actively move themselves around, whereas nekton are organisms that deliberately swim. They are often categorized together because certain individuals within this group will sometimes float and sometimes swim or actively move around.

1. Floaters can be found on or just under the surface, like the mosquito larva which rests with its breathing tube piercing the surface film. When disturbed, it will dive or wiggle downward (nekton). Other organisms float within the water column, especially in still, deep waters such as ponds and lakes. The larva of the phantom midge is an example.

2. Swimmers are well-adapted for maneuvering at the surface or throughout the water. Many swimmers, such as water bugs and water beetles, must occasionally come to the surface for air. The whirligig beetle spends most of its time careening around on the surface, but can zip down through the water when disturbed.

Figure 16: Whirligig Beetle

3. Drift refers to benthic organisms that get carried downstream with the current. Organisms may drift in response to a severe stress, such as very low water or a pollution event. But many benthic organisms drift on a regular basis, perhaps because of overcrowding, to avoid predators, to migrate downstream, or because of a combination of factors.

Neuston is the group of organisms that live on the water surface. The body parts that rest on the surface (such as feet) bend rather than break the surface film, allowing them to walk, skate, or jump without plunging into the water.

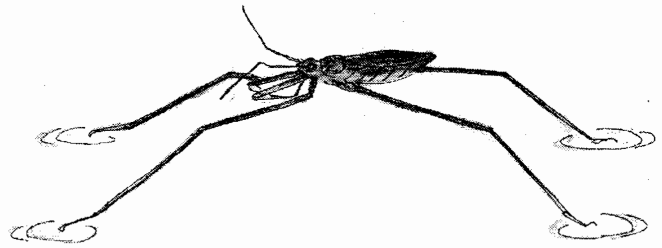
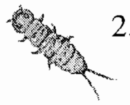


Figure 17: Water Strider

1. Skaters are long-legged insects that glide swiftly over the surface of slower waters. The commonly spotted water strider falls into this category. Close observation reveals the dimple around each foot where it bends the surface film of the water.



2. Jumpers, such as springtails, can jump around on the surface film of still waters.

Figure 18: Aquatic Springtail

After reading this chapter, it may seem as though there are too many details to keep in mind when learning about benthic macroinvertebrates. The best – and least intimidating – approach may be to catch some aquatic "bugs," put them into a well-oxygenated tank, and watch them closely. Take note of all physical features you see and all behavioral traits you observe. Watch interactions between the organisms. You will notice some of the characteristics described above, and you will be able to imagine others as you continue to learn about these fascinating organisms. This indoor introduction will be good preparation for your authentic outdoor learning experience at the river.

Table 2: River Continuum Characteristics

Please note:
*These characteristics are **generalizations** only; individual streams and rivers vary, especially if they are strongly influenced by human activity.*

River Continuum			
Watershed section	headwaters	tributaries	mainstem
Location within the river system	upper reach	mid-reach	lower reach
Stream orders	1 to 3	4 to 5	6 and above
Physical Characteristics			
Gradient	steep	moderate to low	low to flat
Water velocity	fast to moderate	fast to moderate to slow	slow
Streambed material	bedrock and rocks	rocks, cobbles, gravels	sand and/or silt
Channel width	narrow	moderate	wide
Shading (depends on human activities)	high	moderate	low to none
Water temperature	low	moderate	high
Chemical Characteristics			
Dissolved oxygen level	high	moderate	low
Major ions	low	moderate	high
Nutrient level	low	moderate	high
Biological Characteristics			
In-stream plants	[few in-stream plants]	attached mosses rooted plants periphyton	floating plants rooted plants phytoplankton
Food sources	terrestrial (plant parts and organisms that fall in from riparian zone)	instream (aquatic rooted plants, algae, and bacteria)	instream (phytoplankton and fine particulate matter)
Food types	CPOM FPOM	FPOM CPOM periphyton	FPOM phytoplankton
Functional feeding groups	shredders collectors	grazers collectors	collectors
Behavioral groups	clingers sprawlers	various groups	burrowers swimmers

Adapted from Living Waters by Dates and Byrne, River Network, and The American Biology Teacher, May 1977.

PART VI:
LEARNING ACTIVITIES

Activity 12: *Learning About Benthic Macroinvertebrates* (60 minutes)

MATERIALS:

Masters:
- 12A: *Benthic Macro's and Dissolved Oxygen*
- 12B: *Sensitivity Index*
- 12C: *Mayfly*
- 12D: *Stonefly*
- 12E: *Caddisfly*
- 12F: *Comparing Aquatic Insects chart*

Kit Materials:
- Vol. Monitor's FG to Aquatic Macroinvert's

You Provide:
- other benthic macroinvert. field guides
- newsprint sheet or a blackboard
- markers or chalk

Notes:

This activity focuses on Mayfly nymphs, Stonefly nymphs, and Caddisfly larvae because they are important indicators of water quality. Such "top level" organisms require high dissolved oxygen and therefore are intolerant of pollutants that deplete the water of oxygen. They cannot live in degraded water. "Bottom level" organisms (like Midge fly larvae and leeches) can tolerate low dissolved oxygen and, therefore, a higher degree of pollution. (Pollution tolerant organisms can also live in high water quality.)

Objective:

To learn about benthic macroinvertebrates as critical links in the river food web; to understand how to use them to gauge water quality; to compare and contrast organisms.

Activity:

1. Explain that the students will use benthic macroinvertebrates (BMI) to indicate their river's health. They will do this by collecting these aquatic organisms, identifying them, and finding out where they fit in a "Sensitivity Index." Organisms that are sensitive to low oxygen conditions are not generally found in polluted waters, because many kinds of pollution strip the water of dissolved oxygen. If sensitive organisms are present, they indicate relatively high water quality.
2. Show students some pictures of benthic macroinvertebrates (BMIs) using the **Volunteer Monitor's Field Guide to Aquatic Macroinvertebrates** or other guides. Explain that BMIs can be aquatic insects, snails, crayfish, worms, and other small river organisms. Aquatic insects are by far the most numerous of these groups.
3. Explain the term *benthic macroinvertebrate* and go over the information on **Master 12A: *Benthic Macroinvertebrates and Dissolved Oxygen*.**
4. Explain that 3 orders of insects, Stoneflies, Mayflies, and Caddisflies, are key macroinvertebrates because: a) they are important food sources for many river organisms, and b) because their presence indicates good water quality. Refer to **Master 12B: *Sensitivity Index***, and point out the Stoneflies, Mayflies, and Caddisflies on this chart.
5. Show students the **Stonefly, Mayfly, and Caddisfly Masters**. (Note: You may want to make overhead transparencies of these illustrations and project them on the wall.) Through classroom discussion, complete the chart on **Master 12F: *Comparing Aquatic Insects***. (Note: You may want to sketch this chart on a large piece of paper. Save the chart so that students can add to it as they learn more about BMIs.)

Activity Extension:

Collect some BMIs and bring them into the classroom in a cooler to allow students to observe living creatures. Have them look at the unique physical adaptations of these organisms, like the undulating gills on the abdomen of the mayflies and the specific cases built by different caddisfly larvae. Keep their water cool and use an aerator to ensure high levels of dissolved oxygen. If you don't have an aerator, stir up the water frequently and keep it as cold as the water in which they were collected (cold water holds more oxygen than warm water).

Master 12A

BENTHIC MACROINVERTEBRATES
And Dissolved Oxygen

Benthic = bottom-dwelling

Macro = visible to the eye, without the aid of a magnifying lens

Invertebrate = organism without a backbone

Benthic Macroinvertebrate (BMI):

A bottom-dwelling organism without a backbone that is visible to the unaided eye.

Key Facts

A. **BMIs** in a river include insects, crustaceans (such as crayfish), mollusks (such as mussels), and amphipods (such as scuds). They usually cling to the streambed or another solid object in the river so as not to be swept downstream.

B. The level of oxygen dissolved in water greatly determines the quality of that water. High dissolved oxygen levels usually lead to better water quality, and low dissolved oxygen levels usually lead to poorer water quality. (Note: Standing, warm waters, like ponds, often have low oxygen levels but they can be very healthy. Dissolved oxygen levels in standing waters are not as clearly linked to water quality as they are in running waters.)

C. Oxygen is essential for most aquatic animals to survive, just as it is essential for land-dwelling animals to survive. Aquatic organisms use gills to take oxygen from the water, or they come to the water's surface and take oxygen from the air using lungs. Those organisms that breathe air at the surface are less affected by low dissolved oxygen levels and, by extension, low water quality.

D. Dissolved oxygen (DO) in water is determined by several factors:

1) Temperature - cold water holds more DO than warm water;
2) Movement - water that is moving mixes in oxygen from the air;
3) Aquatic plants – they release DO into the water as they grow; but when they die, their decomposition requires DO.
4) Aquatic animals – they take DO out of the water, so their type and abundance can influence dissolved oxygen levels;
5) Organic pollutants – cow manure and human sewage can cause a drop in DO because the microscopic organisms that decompose them take in high levels of DO.

E. The oxygen content of air is a constant 21% (21 units of oxygen in 100 units of air). Oxygen gets dissolved in water in tiny amounts and fluctuates widely (see D. above).

If the dissolved oxygen content of a sample of water is 6 parts per million (ppm), this would equal 0.000006 or 0.0006%. A rise or fall in amounts this tiny has a dramatic affect on aquatic life, and makes dissolved oxygen a critical factor in survival.

F. BMIs can help to gauge water quality in a river. Certain BMIs require high levels of DO; their presence indicates high water quality. Others can tolerate very low levels of DO; their presence can indicate low water quality (but not always, since they can live in water of high quality).

G. To determine water quality, many people use a Sensitivity Index, which organizes BMIs into 3 categories:

1) Top group - BMIs that *require* high DO and high water quality; they cannot tolerate poor conditions (examples: stonefly nymphs, mayfly nymphs, caddisfly larvae);
2) Middle group - BMIs that can tolerate a wide range of DO and water quality levels (examples: crayfish, scuds, damselfly nymphs);
3) Bottom group - BMIs that can tolerate low DO and low water quality levels (examples: leeches, midge larvae, black fly larvae). These organisms can also be found in high water quality.

Refer to **Master 12 B:** ***Sensitivity Index*** for more information.

Key Characteristics that Distinguish Mayfly, Stonefly, and Caddisfly Larvae

Mayfly Larvae (often called Nymphs):

- have one hook at the end of each leg
- usually have three tails
- have gills along the abdomen

Stonefly Larvae (often called Nymphs):

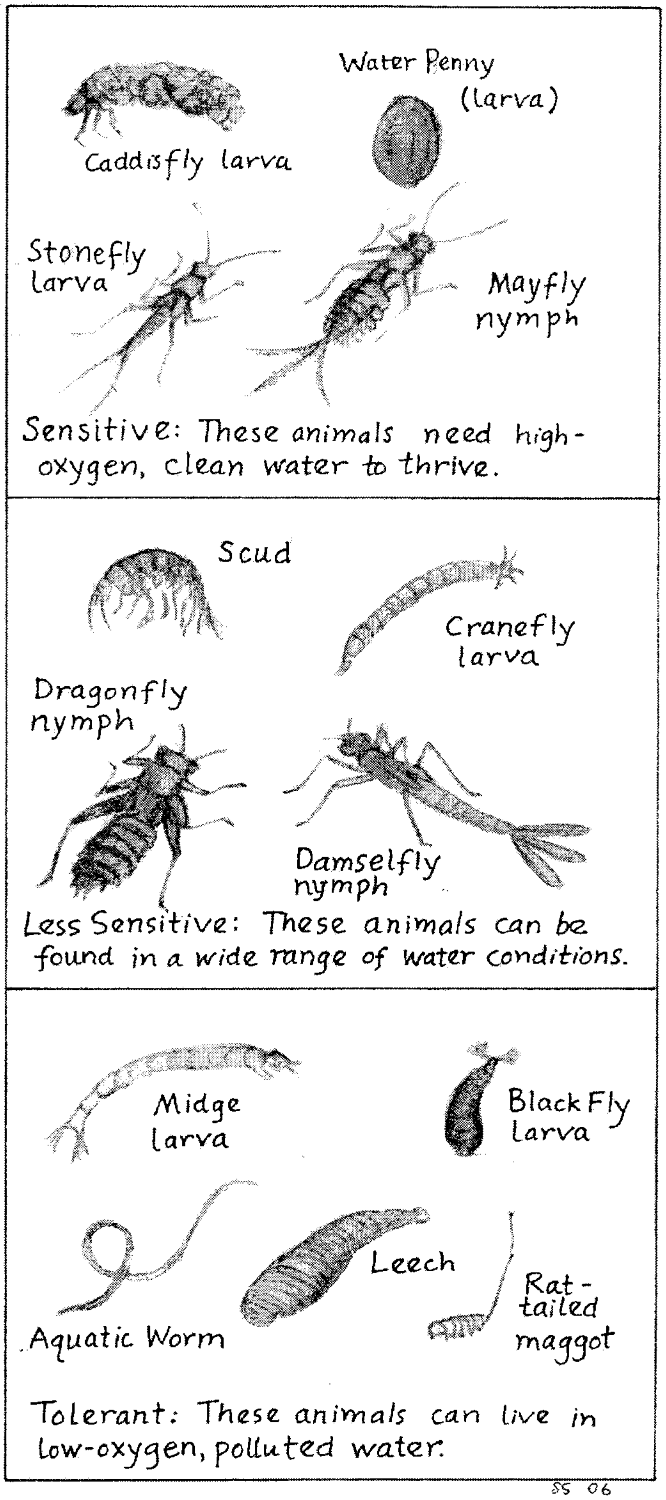
- have two hooks at the end of each leg
- have two tails
- have gills at the base of each leg (on the underside)

Caddisfly Larvae:

- may live in a case that they build
- may live inside nets that they weave
- have a soft abdomen (no exoskeleton)
- have two claws or hooks at the end of the abdomen

Master 12B

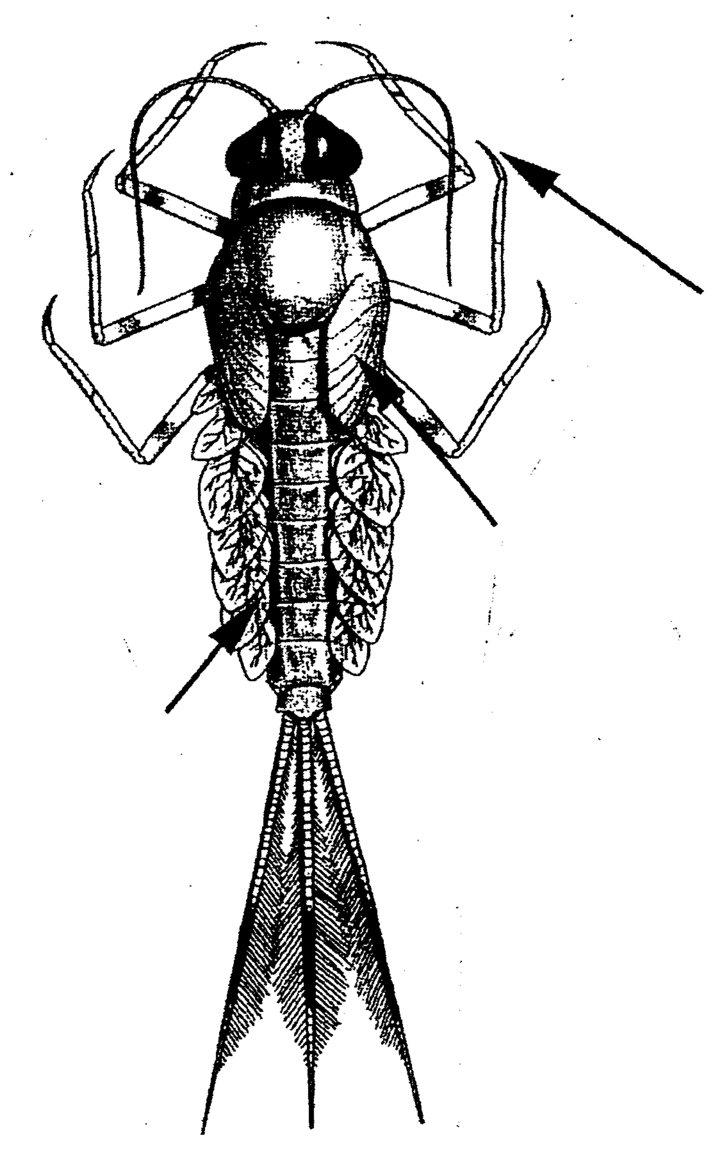
SENSITIVITY INDEX



SS 06

Master 12C

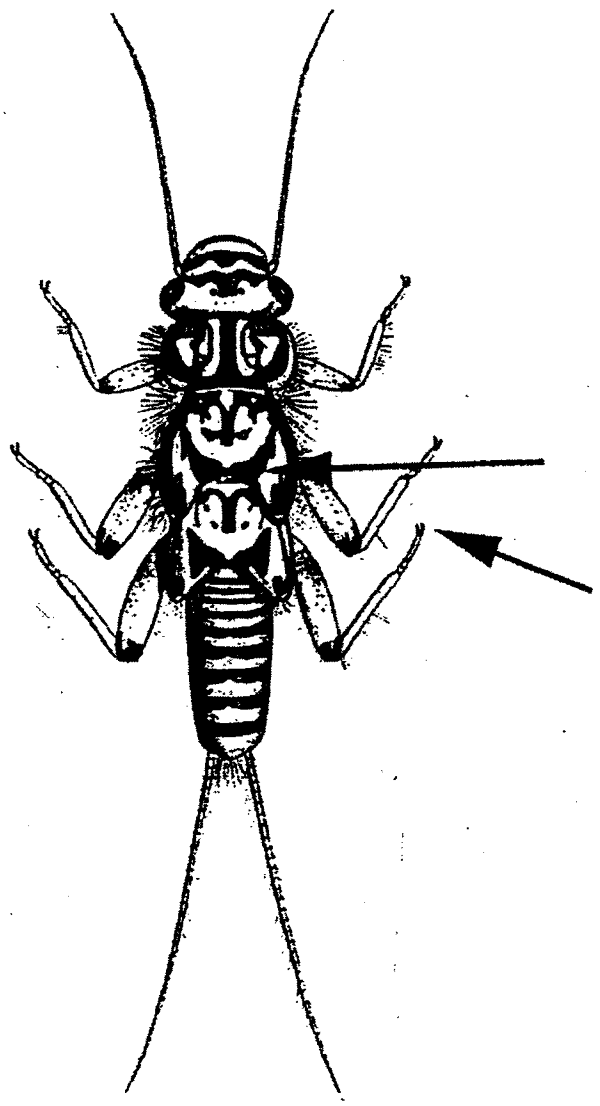
MAYFLY NYMPH ILLUSTRATION



(From Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives, by McCafferty and Provonsha, Jones and Bartlett Publishers, Sudbury, MA, 1998.)

Master 12D

STONEFLY NYMPH ILLUSTRATION



(From <u>Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives</u>, by McCafferty and Provonsha, Jones and Bartlett Publishers, Sudbury, MA, 1998.)

Master 12E

CADDISFLY LARVA ILLUSTRATION

From ***Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives****, by McCafferty and Provonsha, Jones and Bartlett Publishers, Sudbury, MA, 1998.)*

Master 12F

COMPARING AQUATIC INSECTS

Look at the illustrations of Mayflies, Stoneflies, and Caddisflies and complete this table.

Aquatic Insect Orders	Physical Traits Common to All Orders	Physical Traits Unique to Each Order
Mayflies (Order Ephemeroptera)		
Stoneflies (Order Plecoptera)		
Caddisflies (Order Tricoptera)		

Activity 13: *Preparing for the Macroinvertebrate Survey*

Notes:

- *The fieldwork approach in this unit is designed for those without much experience in outdoor river investigations. Refer to the* ***Resources*** *section below for ideas on more precise, systematic fieldwork studies, especially if you're interested in generating valid data.*
- *We recommend using A Guide to Common Freshwater Invertebrates of North America as the primary field guide for your fieldwork since it contains information about stress tolerance (sensitivity to pollution). Refer to the* ***Resources*** *section below for information on finding this book.*
- *We suggest that you send a note home to parents explaining the fieldwork day and how students should dress (in warm layers with waterproof footwear). They should bring an extra set of clothes and footwear to leave in the classroom in case they get wet.*
- *Ask students to bring a snack or provide one for the students to make sure that they have an internal "fire" to keep them warm and happy while outside!*
- *Plan to have at least another adult accompany you and your class to the river. We suggest an adult to student ratio of 1 to 5. Make sure to talk with the adults ahead of time to explain their role while at the river and how they can be most helpful.*

MATERIALS:

Masters:
- 13 A: *Habitat Assessment Info.*
- 13B: *Macroinvert Survey Field Sheet*

You Provide:
- thermometer
- kick screen or other nets
- 4 dishpans
- tape measure
- sieves or kitchen strainers
- hand lenses
- field guides to stream life
- pH, Dissolved Oxygen, and other water test kits (optional)
- camera (digital if possible)

Objectives:

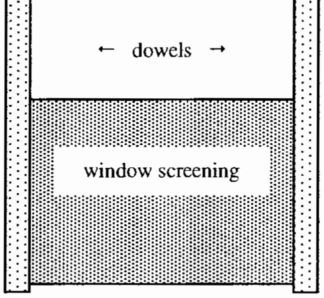
To prepare for an outdoor student investigation; to analyze the living and nonliving parts of a river ecosystem; to understand how people collect information about the world.

Activity:

1. Explain to students that they will conduct a survey of benthic macroinvertebrates and use them as bio-indicators of the health of their river.
2. Go over the **Master 13A: *Habitat Assessment Information*** to help students think about the features of their river site that are important to benthic macroinvertebrates and an assessment of river health.
3. Go over the **Master 13B: *Macroinvertebrate Survey Field Sheet***, making sure that students understand how to complete the survey.
4. Organize students into 4 field groups, explain how the field session will go, and introduce them to the equipment they will use to do their assessment (**tape measure, thermometer, kick screen or other nets, dishpans, hand lenses, field guides,** and anything else you intend to bring with you).
5. Remind students to dress warmly on the fieldwork day and come prepared for the weather. Warm, waterproof footgear is a must. Ask students to bring in an extra set of clothes and footwear to leave in the classroom in case they get wet.

Kick Nets:

You can use a variety of nets for this survey, but we recommend either a "kick net" or "D net" which can be purchased through water quality supply companies. The kick net can be easily made by stapling window screening to 2 dowels like this:



The finish width of the screen (between dowels) should be 1 yard.

Permits for Collecting:

Certain rivers require a state permit for collecting invertebrates. It is always best to check with a representative from the Fish and Wildlife Department in your region to check before collecting flora or fauna. A list of Vermont Rivers and Streams that require permits are listed below:

Lake Champlain tributaries from the lake to the first major falls:
Winooski River (up to Winooski One Dam)
Lamoille River (up to Arrowhead Lake)
Missisquoi River (up to Highgate Dam)
Hungerford Brook (Highgate)
Otter Creek (up to Vergennes Dam)
Lewis Creek (up to Scott Pond)
Dead Creek (Panton, Addison)
Poultney River (up to Carvers Falls)

Other:
West River (Londonderry to Dummerston)
Connecticut River (Guildhall, Lunenburg, and Hartford to Rockingham)
Winooski River and Kingsbury Branch (southern Marshfield to East Montpelier)
Moose River (St. Johnsbury, Concord, Victory)
Nulhegan River (Ferdinand)
Lewis Creek (Monkton, Hinesburg)

For more information and to receive permission to collect please contact:
Vermont Nongame & Natural Heritage Program
Vermont Department of Fish & Wildlife
(802) 244-6812

Master 13A

HABITAT ASSESSMENT INFORMATION

Please read this sheet carefully to prepare for your habitat assessment. Bring this information with you to the river to help in completing the Macroinvertebrate Survey Field Sheet.

Habitat Types

Riffle	Shallow, fast water; surface turbulence (disturbance).
Run	Medium depth; medium-fast water; smooth surface that moves right along.
Pool	Deep, slow water; calm surface.

Substrate (riverbed) Types

Ledge	Bedrock that is exposed in the riverbed
Boulders	Rocks more than 12 inches across
Rubble	Rocks 6 to 12 inches across
Gravel	Rocks 1/4 to 6 inches across
Sand	Particles that are less than 1/4 inch across
Fines	Clay and silt (very tiny particles)

Human Activities Along Rivers (a few examples and their effects on river health)

Soil erosion	Eroding banks send sediment into the river, which warms the water (leading to less dissolved oxygen) and smothers benthic invertebrates and periphyton on rocks
Road along river	Can cause soil erosion; road salt applied in winter washes into river, changing its chemistry; often requires cutting of riparian vegetation, which allows the sun to warm the water (leading to less dissolved oxygen)
Bridge over river	Bridge abutments can change the river's flow and cause it to drop sediment loads, which smother benthic invertebrates and periphyton; road salt washes into the river, changing its chemistry
Livestock pastures	(Near river) Can cause soil erosion and runoff of manure (leading to less dissolved oxygen and overfertilization of water), especially if riparian vegetation is removed
Swimming holes	Bring people into the river, which can lead to soil erosion, cutting of riparian vegetation, and littering

Note: You can ask students to brainstorm a list of human activities along rivers and explain their impacts on the benthic macroinvertebrates in the river.

Master 13B

MACROINVERTEBRATE SURVEY FIELD SHEET

Each group, with adult supervision, will focus on one 20-meter section of the river. Measure out your group's section and complete this sheet.

Check one:	__ 1st section	__ 2nd section	__ 3rd section	__ 4th section

Names of students ____

____

Date ______________________ Date of last precipitation ______________________

Name of stream ____

Watershed ______________________ Nearest town ______________________

Please attach a map of the area with your survey site identified.

A. Stream Section Overview

Temperature of water (use the proper scale): ______°C or ______°F

Time when temperature taken ____

Weather in the last 24 hours ____

Weather now ____

How shaded is the river by trees or shrubs?

___ completely ___ about half ___ only a bit ___ not at all

Dissolved Oxygen (optional) ______ pH (optional) ________

Continue on to section B…

B. Stream Section Sketch *(Use a pencil in case you need to erase and redraw)*:

Direction of Current - Circle one:

⇦ or ⇨

a. Sketch in any habitat types and substrate types you see and label them:

Riffle	Pool	Ledge	Rubble	Sand
Run	Cover (describe)	Boulders	Gravel	Silt

b. Sketch in any examples of human activities and human impacts you see and label them with the corresponding letter:

A. soil erosion	C. bridge over river	E. ______________________
B. road next to river	D. livestock pasture	F. ______________________

Note: E and F are for any other activities or impacts that you notice. If you use them, please write in a descriptio

C. Macroinvertebrate Count

(Adapted from Save Our Streams, Izaak Walton League of America)

Prediction

1. Refer to **A. Stream Section Overview** and **B. Stream Section Sketch**. Given what you know about the factors that affect water quality, please *predict* the water quality of your section, using the following scale:

   ❑ Excellent ❑ Good ❑ Fair ❑ Poor

   Please remember that there are lots of water quality factors that we are not assessing in this fieldwork activity, so there are many unknowns. To get a full understanding of water quality, you would need to do a physical assessment and a chemical assessment in addition to the biological assessment you are about to complete.

2. Explain the assumptions that your Prediction is based on (that is, how did you come to this Prediction?).

Sampling Technique

1. Choose a riffle where the water is fast but not dangerous, the water depth is between 3 and 12 inches, and the bed consists of gravel or small rocks.
2. Place your kick net into the river and stand upstream of it. Completely disturb a 3 foot by 3 foot area in front of your net by kicking the rocks around and rubbing them in the water. Your goal is to dislodge any macroinvertebrates within the area so that the current carries them into your net.

Recording Technique

1. Pick all the organisms from your net that you can see and place them in a basin of water.
2. Identify each organism to the Order level (for example, Mayfly, Beetle, etc.). Check them off if they are present.
3. Follow the directions within the Sampling Site box to complete the sample.

Follow these techniques for each of 3 Sampling Sites

Be careful not to repeat any samples in exactly the same spots.

SAMPLING SITE 1					
Sensitive Organisms		**Somewhat Sensitive Organisms**		**Tolerant Organisms**	
Check if present		Check if present		Check if present	
☐	Caddisfly larvae	☐	Beetle larvae	☐	Aquatic worms
☐	Hellgrammite	☐	Clams	☐	Blackfly larvae
☐	Mayfly nymphs	☐	Crane fly larvae	☐	Leeches
☐	Gilled snails	☐	Damselfly nymphs	☐	Midge larvae
☐	Riffle beetle adult	☐	Dragonfly nymphs	☐	Pouch (and other) snails
☐	Stonefly nymphs	☐	Scuds		
☐	Water penny larvae	☐	Sowbugs		
		☐	Fishfly larvae		
		☐	Alderfly larvae		
		☐	Atherix		
#____ checks x 3 = _____ index value		#____ checks x 2 = _____ index value		#____ checks x 1 = _____ index value	
Now **add together the index values** from each of the 3 columns for your **Total Index Value**: _____________					

Compare this **Total Index Value** to the following ranges of numbers to determine the general water quality of your stream.

<u>Water Quality Rating of Site 1</u>:

___over 22: Excellent ___ 17 to 22: Good ___ 11 to 16: Fair ___ below 11: Poor

SAMPLING SITE 2					
Sensitive Organisms		**Somewhat Sensitive Organisms**		**Tolerant Organisms**	
Check if present		Check if present		Check if present	
☐	Caddisfly larvae	☐	Beetle larvae	☐	Aquatic worms
☐	Hellgrammite	☐	Clams	☐	Blackfly larvae
☐	Mayfly nymphs	☐	Crane fly larvae	☐	Leeches
☐	Gilled snails	☐	Damselfly nymphs	☐	Midge larvae
☐	Riffle beetle adult	☐	Dragonfly nymphs	☐	Pouch (and other) snails
☐	Stonefly nymphs	☐	Scuds		
☐	Water penny larvae	☐	Sowbugs		
		☐	Fishfly larvae		
		☐	Alderfly larvae		
		☐	Atherix		
#____ checks x 3 = _____ index value		#____ checks x 2 = _____ index value		#____ checks x 1 = _____ index value	
Now **add together the index values** from each of the 3 columns for your **Total Index Value**: _____________					

Compare this **Total Index Value** to the following ranges of numbers to determine the general water quality of your stream.

<u>Water Quality Rating of Site 2</u>:

___over 22: Excellent ___ 17 to 22: Good ___ 11 to 16: Fair ___ below 11: Poor

SAMPLING SITE 3					
Sensitive Organisms		**Somewhat Sensitive Organisms**		**Tolerant Organisms**	
Check if present		Check if present		Check if present	
☐	Caddisfly larvae	☐	Beetle larvae	☐	Aquatic worms
☐	Hellgrammite	☐	Clams	☐	Blackfly larvae
☐	Mayfly nymphs	☐	Crane fly larvae	☐	Leeches
☐	Gilled snails	☐	Damselfly nymphs	☐	Midge larvae
☐	Riffle beetle adult	☐	Dragonfly nymphs	☐	Pouch (and other) snails
☐	Stonefly nymphs	☐	Scuds		
☐	Water penny larvae	☐	Sowbugs		
		☐	Fishfly larvae		
		☐	Alderfly larvae		
		☐	Atherix		
#____ checks x 3 = _____ index value		#____ checks x 2 = _____ index value		#____ checks x 1 = _____ index value	
Now **add together the index values** from each of the 3 columns for your **Total Index Value**: ___________					

Compare this **Total Index Value** to the following ranges of numbers to determine the general water quality of your stream.

Water Quality Rating of Site 3:

___over 22: Excellent **___ 17 to 22: Good** **___ 11 to 16: Fair** **___ below 11: Poor**

Choose the site with the best rating and write that rating here: ____________________

INTERPRETING FIELDWORK RESULTS

As a class or in small groups, go over your **Macroinvertebrate Survey Field Sheet** and answer the following questions.

A. Stream Section Overview

1. What was the weather when you did your fieldwork? What was the weather in the last 24 hours before your fieldwork? How does weather affect river habitat?

2. Is your section shaded from the sun? If so, what effect does this have on temperature and dissolved oxygen?

3. If you measured dissolved oxygen and pH, what were your results? How would these conditions affect river habitat?

B. Stream Section Sketch

1. Look at your sketch and describe it in terms of habitat type, substrate type, and human activities. Given your sketch and the features that you noted, write a short description of your section.

SAMPLING SITE 3					
Sensitive Organisms		**Somewhat Sensitive Organisms**		**Tolerant Organisms**	
Check if present		Check if present		Check if present	
☐	Caddisfly larvae	☐	Beetle larvae	☐	Aquatic worms
☐	Hellgrammite	☐	Clams	☐	Blackfly larvae
☐	Mayfly nymphs	☐	Crane fly larvae	☐	Leeches
☐	Gilled snails	☐	Damselfly nymphs	☐	Midge larvae
☐	Riffle beetle adult	☐	Dragonfly nymphs	☐	Pouch (and other) snails
☐	Stonefly nymphs	☐	Scuds		
☐	Water penny larvae	☐	Sowbugs		
		☐	Fishfly larvae		
		☐	Alderfly larvae		
		☐	Atherix		
#____ checks x 3 = _____ index value		#____ checks x 2 = _____ index value		#____ checks x 1 = _____ index value	
Now **add together the index values** from each of the 3 columns for your **Total Index Value**: ____________					
Compare this **Total Index Value** to the following ranges of numbers to determine the general water quality of your stream.					
Water Quality Rating of Site 3:					
___**over 22: Excellent**		___ **17 to 22: Good**	___ **11 to 16: Fair**	___ **below 11: Poor**	

Choose the site with the best rating and write that rating here: ____________________

INTERPRETING FIELDWORK RESULTS

As a class or in small groups, go over your **Macroinvertebrate Survey Field Sheet** and answer the following questions.

A. Stream Section Overview

1. What was the weather when you did your fieldwork? What was the weather in the last 24 hours before your fieldwork? How does weather affect river habitat?

2. Is your section shaded from the sun? If so, what effect does this have on temperature and dissolved oxygen?

3. If you measured dissolved oxygen and pH, what were your results? How would these conditions affect river habitat?

B. Stream Section Sketch

1. Look at your sketch and describe it in terms of habitat type, substrate type, and human activities. Given your sketch and the features that you noted, write a short description of your section.

C. Macroinvertebrate Count

1. Restate your Prediction here.

2. Of all 3 of your Sampling Sites, what was your best Water Quality Rating? How does this compare to your Prediction? Please explain.

3. If your Water Quality Rating was <u>less than excellent</u>,
    a. What stresses do you think exist for the macroinvertebrates that live in your section? Please list all you can think of.

    b. What can people do to reduce or eliminate these stresses (if they exist)?

4. If your Water Quality Rating was <u>excellent</u>,
    a. What can people do to maintain this high level of water quality?

5. How does water quality affect people? Think about human health, recreation, economics, etc.

Activity 14: *Scientific Drawings of BMIs* (60 minutes)

MATERIALS:

Masters:
- 14: *Important Factors in Scientific Drawings*
- 12C, 12D, 12E: *Mayfly, Stonefly, Caddisfly*

Kit Materials: none

You Provide:
- newsprint sheets
- markers
- scientific drawings from field guides, other references
- artistic drawings
- sheets of paper or notebooks (Student BMI Log)
- students' Compar. Aquatic Insects charts from Activ. H

Objective:
To study the anatomy of aquatic insects in order to identify them; to understand how anatomy reflects adaptations to habitat and niche; to learn scientific observation skills by drawing an organism.

Background Information:
Scientific drawing involves accurately illustrating an object, whether from a picture or the real thing. It requires important scientific skills such as careful observation, accurate measurement and color, attention to detail, a concept of scale, and identifying and labeling important parts.

By scientifically drawing organisms, students come to understand essential characteristics of these organisms and begin to see distinctions between them. Students also see how the environment literally shapes an organism, and so begin to understand how anatomy reflects ecology. The concepts and skills involved can be used for various scientific studies and refined all year long.

Anyone can do scientific drawing. Yet some students may believe that they are unable to draw and shy away from it. Because it provides concrete guidelines, scientific drawing may help students feel more confident about their drawing skills while reinforcing the concepts that they are learning in the unit.

Activity:

1. Explain to students that, as part of their river investigation, they are going to collect and sort BMIs. Therefore, they need to understand how to identify them and how their anatomy helps them survive in the river.
2. Show students various examples of scientific drawings from field guides and other scientific references. Ask students to ask themselves:
   - What is the illustrator trying to teach me with these drawings?
   - What do I want to learn from these drawings?
   - What details are helpful and useful?
   - What details are unclear or confusing?
3. Now show students an example of an artistic drawing that expresses a thought but may not help the observer learn about a real object.
4. Have students brainstorm the kinds of characteristics that make for an effective scientific drawing. Write this list on a piece of newsprint.
5. Go over **Master 14: *Important Factors for Scientific Drawings***, to ensure that students understand the important characteristics of good scientific drawings.
6. Have students brainstorm the kinds of characteristics that make for an effective artistic drawing. Write down their thoughts on newsprint. Their lists may look something like this:

Scientific Drawings *(sample student responses)*	**Artistic Drawings** *(sample student responses)*
All important details included Parts are in accurate proportion to each other Accurate colors and shapes Someone should be able to identify the item from the drawing Should be like a "photograph" of the item	Expresses a thought, feeling, or idea Creative use of details, colors, numbers of parts, proportions, etc. May include imagined parts May combine items found in nature in new ways

7. Now revisit the students' **Master 12F:** ***Comparing Aquatic Insects*** chart and have them look again at the **Stonefly, Mayfly,** and **Caddisfly Illustrations**. Have them write in any features that they missed the first time.
8. Tell students that they are going to do scientific drawings of a sampling of BMIs they are likely to find in their river. They will create a BMI Log which will help them learn about various macroinvertebrates and identify the ones they find during their fieldwork.
9. Hand out sheets of paper or notebooks. Make available various field guides or keys of macroinvertebrates. (You could also pass around live organisms you have collected.) Have students focus on one organism and draw it in their log. You could have all students focus on one kind of organism at a time, or have various students draw different organisms at one time. Students can work on their log over several sessions. Each entry should include the following information:

    Title of organism (common and/or scientific name(s))

    Scale (a line that shows the organism's actual length)

    Labeled parts and details using scientific language

    Color (if appropriate)

    Each student log should include the following Orders of insects, since these are the important indicators of high water quality:

    Mayflies (Order Ephemeroptera)

    Stoneflies (Order Plecoptera)

    Caddisflies (Order Tricoptera)

Students might also include some of these Orders of insects and other macroinvertebrates:

- True Flies (Order Diptera)
- Beetles (Order Coleoptera)
- Dragonflies and Damselflies (Order Odonata)
- True Bugs (Order Hemiptera)
- Crayfish (Order Decapoda)
- Scuds (Order Amphipoda)
- Mollusks (Phylum Mollusca)
- Segmented Worms (Phylum Annelida)

Activity Extension:

Have each student choose one organism on which to make a presentation to the class. Where is it found in the river? That is, what is its river habitat? (riffles, pools, under rocks, water surface, etc.) What does it eat? What is its sensitivity to DO and pollution? How do its physical adaptations reflect its habitat and lifestyle?

Master 14

IMPORTANT FACTORS IN SCIENTIFIC DRAWINGS

A. The Drawing

Details - The parts and shapes of your object. Decide what information you want to communicate through your drawing and include the details that help to accomplish this goal. Too little detail may leave out important information; too much detail may overwhelm the observer and obscure your drawing.

Spatial Organization - Drawing all parts of the object in the right place in relation to each other.

Perspective - The appearance of details of the object as determined by their relative distance and positions. Perspective can help the illustrator create a 3-dimensional picture.

Texture - Showing how the object feels with the use of color and shading. For example, if the object is rough, you want the drawing to look rough.

Color - When doing a scientific drawing, try to match the colors on the real object as closely as possible since they give the viewer important information about the object.

Shading - Using a mixture of black, white, and color to create the differences in color and shadow on the real object.

Scale - A ratio that represents the size of the object in a drawing to the object in real life. Scientific drawings of small organisms are often larger than the real organisms to show details, so the illustrator might draw a line (|-----|) that indicates the actual size of the organism.

B. Supporting Information

Label - A label is a word or short phrase that tells the observer the name of a part of your drawing or explains its function. Only label the parts of the picture that would help another person learn something new or important.

Key - The key is a list of symbols and their meanings. If you use a symbol to **label** something in your drawing, label it in the key. The key should also tell the observer the **scale** of your picture.

Title - A word or phrase that *names* your drawing and concisely describes what it is.