Benthic Macroinvertebrates:

They Maybe Bottom-Dwellers but When It Comes to Clean Water – They're Tops!

A comprehensive summary of introductory learning activities to be completed prior to field work

Virginia Science SOLs

6.5, 6.7, LS.4, LS.5, LS.7, LS.8, LS.10 and LS.11

Key Concepts

life cycles of aquatic organisms, physical adaptations, in-stream food webs, aquatic habitats, environmental influence on organisms and biological water quality monitoring

Vocabulary

benthic macroinvertebrate, complete and incomplete metamorphosis, adaptation and microhabitat

Setting

classroom

Summary

Students participate in a wide variety of introductory learning activities including viewing power point presentations on benthic macroinvertebrates, researching and reporting on a specific aquatic organism and illustrating or creating a model.

Learning Objectives

Students will be able to:

1. recognize juvenile and adult stages of common aquatic organisms,
2. provide examples of both physical and behavioral adaptations exhibited by benthic macroinvertebrates as they relate to life in flowing water, and
3. associate key macroinvertebrate species as being members of Groups I (intolerant) II (moderately tolerant) or III (tolerant) in terms of water pollution sensitivity.

Background Information

Surveying the **benthic macroinvertebrates** of a particular stream or small river not only provides insight in the system's relative water quality, but the organisms themselves serve as real life examples of different life cycles and aquatic adaptations. Benthic or bottom-dwelling macroinvertebrates are animals that lack internal skeletons, but are visible to the naked eye (typically larger than 0.5mm.) They include a vast array of aquatic insects, worms, snails, clams and crustaceans (crayfish, freshwater shrimp) and arachnids.

Benthic macroinvertebrates are routinely used as biological indicators of water quality and overall stream health because they vary significantly in their tolerance of water pollution. For example, mayflies, stoneflies and most types of caddisflies require relatively cool, clear, well-oxygenated water and are sensitive to environmental changes brought on by water pollution. Generally, these intolerant organisms are said to be members of Group I. Moderately tolerant or somewhat sensitive dragonfly nymphs and crayfish are members of Group II whereas leeches, aquatic worms and most true flies (i.e. black flies and midges) which can tolerate warmer, more turbid conditions comprise Group III. Considered as a whole, the ratio of tolerant to intolerant organisms can indicate the overall health of the waterway. Unlike fish, macroinvertebrates can't escape sudden changes in the aquatic environment, such as an influx of pollution, by swimming away. Since their life cycles are relatively short, changes in their populations can be noted relatively quickly. Environmental regulatory agencies, university-based researchers and volunteer citizen monitoring groups use a variety of mathematical formulas that incorporate different species of marcroinvertebrates to provide an overall water quality score. Benthic macroinvertebrate Group III is sometimes divided into a fourth group for water quality monitoring purposes.

Inhabiting most Virginia streams and small rivers, are macroinvertebrates that undergo a wide range of life spans. Among the most noted, are certain kinds of mayflies that only live a few hours as winged adults and lack mouthparts, for their only mission is to produce fertile eggs that begin a new cycle of life. Aquatic insects provide examples of both **complete and incomplete metamorphosis**. Students will likely recall the complete metamorphosis of the butterfly from egg to larva to pupa to adult. Insects such as true flies, beetles and caddisflies, experience a similar life cycle in the aquatic environment.

Other insects, such as dragonflies, mayflies and stoneflies undergo a less complex set of changes. They also begin their lives in streams as an egg which becomes a larva. However, the larval form, often referred to as a nymph, changes directly into an adult. In general, nymphs resemble their adult counterparts much more than the larval forms of insects which undergo complete metamorphosis. If students examine dragonfly nymphs closely, they may see the wing buds on the top of the abdomen and be able to envision the future adult dragonfly. Similarly, the pronged tails of the mayfly nymph and adult mayflies will typically have the same basic shape.

Just like other organisms, aquatic macroinvertebrates are specially adapted to their environment. **Adaptations** are specialized characteristics that animals and plants have developed over time in response to environmental pressures. They may be physical features or specialized behaviors. These tools help the organism to survive in specific conditions. Stream and river dwellers are often outfitted with structural features that enable them to survive the often harsh environment of fast-moving water. Many have flat, streamlined bodies that allow them to escape the current by squeezing beneath and between rocks on the stream bed. Others have grasping claws or suction cups on their bodies to prevent them from being swept away in the swift-flowing current.

Many aquatic organisms also have physical adaptations that help them collect food from the moving water. The net-building caddisfly larva attaches a funnel-shaped net to a rock, and then periodically creeps out of its crevice to harvest the tiny plants and animals caught in the mesh. Black fly larvae have feather brushes on their head that comb bits of food from the passing water. Black fly larvae line up on rocks in dense colonies that look like carpets of black moss. With their forelegs clamped tightly to the rock's surface, they let their bodies float out with the water's flow. Should the larva lose its grip, it simply hauls itself back with a silken lifeline, another adaptation that aids in survival in the running water of a stream environment.

Behavioral adaptations are not as easily observed but are quite critical to the life of many aquatic organisms. Hibernation is a common behavioral adaptation. When conditions are unfavorable, the organism will slow its metabolic rate, and enter a special deep sleep until conditions improve. Many insects have adapted behaviors to respond to increasing water temperature. When the water gets too warm and dissolved oxygen decreases, the insects will move to cooler, faster water. Stoneflies have a very unique behavioral response to low dissolved oxygen levels. They do "push-ups" to increase the amount of water flowing over their gills.

Both physical and behavioral adaptations benefit aquatic organisms when it comes to obtaining food. When classified by feeding habit, macroinvertebrates fall into four main functional feeding groups; shredders, scrapers, collectors and predators. As stream and rivers follow their normal course,

Background, continued

a predictable change in habitat, food base and thus dominant marcoinvertebrate feeding group occurs. Shredders have chewing mouthparts that allow them to feed on pieces of decaying organic matter that falls into the stream. These organisms tend to inhabit headwater streams and other areas with a high percentage of canopy cover. Most stoneflies are shredders.

Scrapers are more common in the middle reaches of a watershed where they can graze on rock and wood covered algae. Snails and water pennies feed in this manner. Many scrapers have flat, streamlined bodies or suction disks that enable them to hang on in current. Collectors depend on fine particles of organic matter, either filtering or gathering in from the water. Black fly larvae attach themselves to the substrate and filter particles using sticky hair-like appendages Many gathering collectors are adapted for burying into bottom sediments. Collectors occupy all parts of the stream and river continuum because fine particles are present in all parts of the system. However, they typically make up larger percentage of the macroinvertebrate population in the lower watershed where sediments accumulate and the habitat is less suitable for shredders and scrapers.

Predators consume other macroinvertebrates and inhabit all parts of the stream and river system. They have physical adaptations suitable for capturing prey such as raptorial forelegs and strong opposable mouthparts for biting and chewing. Dragonfly nymphs and dobsonfly larva exhibit many of these characteristics. Predators that pierce their prey and suck body fluids have tubular mouthparts. *(For an extensive list of adaptations and food sources, please see the chart included in this lesson plan.)*

A final way to group macroinvertebrates is by preferred **microhabitat**. Macroinvertebrates inhabit all the major in-stream habitats including riffles, pools, runs and glides. Since riffles are the most rich in oxygen, they tend to be home to those macroinvertebrates that are sensitive to pollution. A variety of microhabitats provide food and shelter, including gravel bottoms, finer sediments, plants, detritus (decaying organic matter) and surfaces of rocks and woody debris. Several organisms, such as freshwater mussels, burrowing mayflies, leeches and aquatic worms, prefer the more stagnant areas of fine sediments.

Materials

- Benthic Macroinvertebrate poster, field guide or identification sheets or from your Soil and Water Conservation District. (The guide or info sheets should include information on the organism's pollution tolerance level.)
- Internet Access
- Poster board or assorted craft supplies – i.e. drawing paper, markers or crayons, egg cartons, paper towel rolls, tissue paper, pipe cleaners, construction paper, tape, glue, plastic eyes, etc.

Procedure

1. Use visual aids, such as a benthic macroinvertebrate poster or powerpoint presentation, to introduce the students to the key concepts from the Background Information section. To download the powerpoint presentation "Macroinvertebrates as Bioindicators of Stream Health" by Michigan Clean Water Corps, go to http://wupcenter.mtu.edu/education/stream/macroinvertebrate.pdf.

   An engaging way to review the life cycles of common aquatic organisms is to conduct the lessons "Water Babies" from Shelburne Farms *Project Seasons* ISBN 0-9642163-0-2 or "Are You Me?" for Project WILD Aquatic. Pollution sensitivity levels can be reviewed by playing "Macroinvertebrate Mayhem" in Project WET (see Resources of this curriculum). ***Please note:*** When playing this game, the "handicaps" or adaptations given to the students who are role-playing pollution sensitive organisms can be simplified. Instead of using a sack, students typically just hop, for example.

Procedure, continued

2. In small groups of 2-3 students (who can later combine for a field day group of 5), assign students to conduct research and become the "resident expert" on one aquatic species likely to be encountered during the field investigation. Suggestions include: mayfly, stonefly and dragonfly nymphs, case building caddisfly larvae, common netspinners (a more tolerant caddisfly,) crayfish, gilled snails, lunged snails, freshwater clams, aquatic worms, leeches and mosquito, blackfly and midge larva. *(On page 7, an optional graphic organizer is included with this lesson.)*

3. As a part of preparing to present a report to the class, student pairs or groups can make visual aid (poster or craft model) of their organism that highlights its physical adaptations to its environment and denotes its water pollution sensitivity level. While student groups are giving reports, ask the class to identify relationships between the aquatic organisms in order to reinforce other basic concepts such as life cycle stages, energy flow and food webs.

4. ***Alternative* –** Instead of creating a model of an actual aquatic organism, students can invent a macroinvertebrate that exhibits one or more adaptations described on the cards contained with this lesson.* The adaptation cards[1] can be randomly distributed to the small groups or linked to assigned portions (microhabitats) of the stream. For example, a group of students can be asked to design an organism that "fits between rocks and crevices" and lives in a riffle.

   ** This activity adapted from* Pond and Stream Safari: A Guide to the Ecology of Aquatic Invertebrates *by Karen Edelstein. Published by Cornell Cooperative Extension, 4-H Leader's Guide 147L24 ISBN # 1577532546*

   1. Adaptation cards follow Assessment and Resources sections.

Assessment

Small group macroinvertebrate project may be assessed on organization, thoroughness, grammatical correctness, and presentation of the report, and the accuracy and creative use of materials for the model. Students' ability to make connections to key concepts should be demonstrated through group discussion.

Resources

An aquatic critters slide show is available on-line from the Missouri Botanical Garden at http://mbgnet.net/fresh/rivers/index.htm

A Guide to Common Freshwater Invertebrates of North America, by J. Reese Voshell, Jr., and illustrated by Amy Bartlett Wright (2002). Recognized as the field guide of choice for beginning and intermediate identification and study of freshwater invertebrates of the United States and Canada. ISBN 978-0-939923-87-8 is available from Virginia Tech Department of Entomology, Blacksburg, VA 24061, Phone: (540) 231-6341; Fax: (540) 231-9131 or http://web.ento.vt.edu/ento/showPub.jsp?pubNum=205

Other helpful sites include: Virginia Save Our Streams www.vasos.org under "Hotlinks to VA SOS field sheet downloads"

Biological Indicators of Watershed Health: Benthic Macroinvertebrates in our Waters at www.epa.gov/bioindicators/html/benthosclean.html includes a wealth of pictures and info

Resources, continued

Life Cycle of Aquatic Insects at www.epa.gov/bioindicators/html/lifecycle.html;

Mayflies of the United States at www.npwrc.usgs.gov/resource/distr/insects/mfly and Stoneflies of the United States at www.npwrc.usgs.gov/resource/distr/insects/sfly/index.htm

An example of student work can be found at http://www.bgsd.k12.wa.us/hml/jr_cam/marcos/resources.html

Adaptation Information for Procedure 4

Adaptation	***Real Aquatic Insect Examples***
Swims through water	*water boatman, water bugs, diving water beetle, scavenger beetle*
Stays on top of water surface	*water Strider, whirligig beetle*
Clings to weeds and vegetation	*damselfly nymphs, dragonfly nymphs*
Eats periphyton (algae on rocks)	*caddisfly larvae, water penny beetle larvae, some mayfly nymphs, snails*
Eats detritus (decomposing organic material)	*caddisfly larvae, mayfly nymphs*
Eats other insects	*dragonfly nymphs, damselfly nymphs, water striders, water bugs, larger stoneflies, beetles (larvae and adult), dobsonflies, fishflies, alderflies*
Digs down into silty/sandy bottom	*burrowing mayflies*
Fits between rocks and crevices	*water pennies, flathead mayflies, stoneflies*
Filters out fine particulate organic matter (FPOM)	*net-spinning caddisfly larvae, blackfly larvae, some mayfly nymphs*
Dives from surface of water to bottom	*predaceous diving beetle, scavenger beetle, water boatman, backswimmer*
Clings to top rocks on stream bottom	*common stoneflies*
Burrows into mud	*burrowing mayflies*
Eats course particulate organic matter (CPOM)	*cranefly larvae, case-building caddisfly larvae, small stonefly nymphs, scuds, aquatic sowbugs*
Stays just below the surface	*mosquito larvae, water scorpion*

Adaptation Cards for Procedure 4

Swims through water	Fits between rocks and crevices
Stays on top of water surface	Filters out fine particulate organic matter (FPOM)
Clings to weeds and vegetation	Dives from surface of water to bottom
Eats periphyton (algae on rocks)	Clings to top rocks on stream bottom
Eats detritus (decomposing organic material)	Clings to bottom of rocks on the stream bottom
Eats other insects	Eats course particulate organic matter (CPOM)
Digs down into silty/sandy bottom	Stays just below the surface

Benthic Macroinvertebrate Research Notes