WATER QUALITY LESSON – Bioindicators Of Stream Health: Benthic Aquatic Macroinvertebrates



TOPIC: Biological Assessment of Stream Water Quality

AUTHOR: Beaver Water District

CLASS TIME NEEDED:

- **Two Class Periods (45-60 minutes)**: Research and discuss local water quality issues, related terms, and monitoring procedures. (See MATERIALS List p. 2).
- **Two Class Periods (45-60 minutes),** if there is a nearby creek, pond, or other natural water body **or Half-day Field Trip (3-4 Hours)**: Investigate a creek, lake, pond, or stream to find macroinvertebrates. Turn over rocks or collect with kick-nets and seines (See MATERIALS List p. 2).
- **One Class Period (45-60 minutes)**: Inventory macroinvertebrates from observations and collection and complete survey sheet (p. 6), then make a water quality determination as an indicator of water body health.

SUBJECT/GRADE LEVEL: K-12 - Physical Science/Biology/Earth Science/ETS/Environmental Science

ARKANSAS SCIENCE STANDARDS:

Grades K-2

- Physical Science – K-PS3-1, K-PS3-2,
- Biology – K-LS1-1, 1-LS1-2, 1-LS3-1, 2-LS4-1
- Earth Science – K-ESS2-2, K-ESS3-1, K-ESS3-3, 2-ESS2-2, 2-ESS2-3
- Engineering, Technology, & Application of Science – K-ETS1-2, 2-ETS1-2

Grades 3-4

- Physical Science – 4-LS1-1, 4-LS1-2
- Biology – 3-LS1-1, 3-LS3-2, 3-LS4-2, 3-LS4-3, 3-LS4-4, 4-LS1-1
- Earth Science – 3-ESS2-2, 3-ESS3-1, 4-ESS2-1, 4-ESS2-2, 4-ESS3-2
- Engineering, Technology, & Application of Science – 3-ETS1-2, 4-ETS1-2

Grades 5-8

- Physical Science – 5-PS1-1, 5-PS1-2, 5-PS1-4
- Biology – 5-LS2-1, 6-LS1-5, 7LS2-2, 7-LS2-5, 7-LS2-1, 7-LS2-4, MS-LS2-5,
- Earth Science – 5-ESS2-1, 5-ESS2-2, 5-ESS3-1, 6-ESS3-3, 6-ESS3-4
- Engineering, Technology, & Application of Science – 5-ETS1-2, 6-ETS1-2, 8-ETS1-18-ETS1-2, 8-ETS1-4

Grades 9-12

- Physical Science - PSI-LS2-7, PSI-LS4-5, PSI-ESS2-1, PSI-ESS3-1, PSI6-ETS1-1, PSI6-ETS1-2, PSI6-ETS1-3, PSI6-ETS1-4
- Biology – BI-LS2-1, BI-LS2-2, BI-LS2-6, BI-LS2-7, BI-LS4-5, BI3-ETS1-3, BI-ESS2-2, BI-ESS2-4, BI-ESS2-5, BI-ESS3-5, BI6-ETS1-2, BI6-ETS1-3, BI-ESS3-1, BI-ESS3-2, BI-ESS3-3, BI-ESS3-4, BI-ESS3-6, BI7-ETS1-1, BI7-ETS1-4
- Earth Science - ES-ESS2-2, ES-ESS2-5, ES2-ETS1-1, ES2-ETS1-3, ES-ESS3-3, ES-ESS3-4, ES-ESS3-6, ES3-ETS1-1, ES3-ETS1-2, ES3-ETS1-4
- Environmental Science - EVS-ESS2-2, EVS-ESS2-3, EVS-ESS2-5, EVS-ESS2-6, EVS-ESS3-5, EVS1-ETS1-1, EVS-LS2-1, EVS-LS2-2, EVS-LS2-6, EVS-LS2-8, EVS3-ETS1-3, EVS-ESS3-1, EVS-ESS3-3, EVS-ESS3-4, EVS-ESS3-6, EVS-LS2-7, EVS-LS4-6, EVS4-ETS1-3

LEARNING PERFORMANCE TARGET(S): (learning expectations for this lesson; combines a science practice, crosscutting concept and core idea embedded in the lesson)

Students will:

- Learn about the types of invertebrate organisms and their diversity in a stream and relate the invertebrate community to overall water quality.
- Acquire expertise to enter a stream, collect and identify benthic macroinvertebrates, then assess the degree to which the stream may be impacted by pollution, determine potential contaminant sources, and propose possible solutions for preserving or improving water quality.

SCIENCE AND ENGINEERING PRACTICES:

Lab work, field work, acquire data, graphing, planning and carrying out investigations, analyzing and interpreting data, asking questions and defining problems.

CROSSCUTTING CONCEPTS:

Structure and Function, Stability and Change

CCSS CONNECTIONS: (include mathematical concepts and reading, writing, speaking and listening opportunities in the lesson). All exist throughout the lesson. ELA/Literacy, Mathematics

MATERIALS:

- **Bioindicators of Environmental Health: Benthic Macroinvertebrate Information Sheet with Stream Macroinvertebrate Inventory Report** (p. 5-6), Izaak Walton League of America "Key To Macroinvertebrate Life In A River" (p. 7) and photographs (p. 9-14)
- **Izaak Walton League of America Resource: Save Our Streams (SOS) Monitoring Equipment - www.iwla.org/resource/sos-equipment**
- **Macroinvertebrate Sampling Equipment**: Kick- or D-nets, seines (500 µm) (panty hose tied between sticks have been used), white or light-color dish pans, ice cube trays, hand-held magnifying glasses, spoons, plastic pipettes or eyedroppers
- **Beaver Water District Website – www.bwdh2o.org**
  - Lake Data / Beaver Lake Raw Water Quality, Clean Water Act (CWA) 1972, Beaver Lake & Its Tributaries: Source Water Quality Reports - www.bwdh2o.org/beaver-lake/lake-data/
  - Source Water Protection - www.bwdh2o.org/beaver-lake/source-water-protection/
- **University of Arkansas Department of Agriculture Extension Service (UAEX)**
  - Water Quality Webpage - www.uaex.edu/environment-nature/water/quality/
  - Publication FSA9528 "What Is Water Quality?" - www.uaex.edu/publications/pdf/FSA-9528.pdf
  - ***BASIC/Arkansas Watershed Steward Handbook*** **Publication AG1290 - www.uaex.edu/environment-nature/water/docs/ag1290.pdf**
- ***BASIC/*Ozarks Water Watch (OWW)/Beaver Lake StreamSmart: *Guide to Water Quality Monitoring for Volunteers in the Beaver Lake Watershed* (Revised 2018) - owwbeaverlake.org/wp-content/uploads/2018/07/A-Guide-to-Water-Quality-Monitoring-for-Volunteers-in-the-Beaver-Lake-Watershed-2018_7.10.2018.pdf**
- ***ADVANCED*/National Park Service (NPS) Protocol for Monitoring Aquatic Invertebrates at Ozark National Scenic Riverways, MO, & Buffalo National River, AR** (Natural Resource Report NPS/HTLN/NRR—2007/009) - irma.nps.gov/DataStore/DownloadFile/153098. Download & go to Standard Operating Procedures SOP 3: Sampling Invertebrates & Collecting Habitat Data & SOP 4: Laboratory Processing & Identification of Invertebrates pp. 51-77.

TEACHER PREPARATION:

Find a local water source to sample. Prepare material and space according to the 7 E's instructions (p. 4).

BACKGROUND INFORMATION/CONTENT:

Problem Question:

What is the role of macroinvertebrates and how does their presence help determine the quality of water?

Teacher:

Access/download and review the webpages or publications in the MATERIALS list, particularly the **Arkansas Watershed Steward Handbook** and the **StreamSmart: Guide to Water Quality Monitoring for Volunteers in the Beaver Lake Watershed (Revised 2018)**. These sources include many water quality lesson materials, information, and instructions that will facilitate learning about tolerant/intolerant species of macroinvertebrates, sampling equipment, and stream water quality monitoring procedures.

Student:

Students need basic knowledge of stream anatomy (See "Stream Anatomy & Function" Lesson), pollution-sensitive invertebrates, pollution sources, water quality monitoring and sampling methods (see p. 2 MATERIALS List). Read "What Is Water Quality?" and access additional information on websites in MATERIALS list for background on stream pollution and the consequences of pollution. Do online research for articles about Northwest Arkansas Water Quality issues and innovative approaches to preserving or improving quality of water on the surface and below ground.

Keywords

Macroinvertebrates: Spineless organisms that are large enough to be observed without magnification, found under rocks and leaf packs, and indicators of water quality.

Intolerant species: Macroinvertebrates that cannot survive (tolerate) in higher levels of pollution.

Tolerant species: Macroinvertebrates that can survive (tolerate) higher levels of pollution.

Point pollution: Pollution coming from a specific source that can be identified clearly. (Ex. Pipe discharging directly into a stream)

Nonpoint pollution: Pollution from an unknown source that is washed into surface water by rainfall (Ex. Runoff from a cow pasture or parking lot)

7E'S Macroinvertebrate Bioindicators Of Stream Health

Elicit

Read news articles about water quality in your area. Have students brainstorm possibilities that may be causing these problems. The students will also have to brainstorm within their group to determine all possible sources of pollution upstream.

- Read an article (http://www.epa.gov/) to the class about pollution levels in a body of water downstream from your location. Discuss the article and the impacts of humans on water quality.
- Discuss where your drinking water comes from and who impacts the land around your water source.
- Explain "Everyone lives downstream."

Engage

Have students look at macroinvertebrate identification sheets or flashcards and determine pollution tolerant and intolerant species.

- Describe stream anatomy (Lesson 6 Stream Anatomy & Function - riffles, runs, pools, etc. . . .).
- Describe where to find the macroinvertebrates (p. 5).
- View pictures of actual organisms (pp. 9-14). Show invertebrate flashcards (www.flinnscientific.com) or access websites in MATERIALS List (p. 2) to see photographs online.
- Hand out a macroinvertebrate identification key (p. 7) or download **"Aqua Bugs"** app from: Izaak Walton League of America - www.iwla.org/conservation/water/save-our-streams/monitoring-101
- Explain the pollution tolerant and pollution intolerant sections of a macroinvertebrate sheet (p. 5). For a truly inquiry-based lesson, allow students to first go out and collect whatever macroinvertebrates they can find and have them identify and sort as pollution tolerant or intolerant. Have students present their determination of stream health based on their findings. Then proceed with following steps. After the second round of sampling, have the students compare their results to their initial findings.
- Read "What is Water Quality?" in MATERIALS List (p. 2) and research other sources of information about pollution sources, the discuss possible sources of pollution (point/nonpoint/urban/agricultural) upstream from sampling site(s).

Explore

Take students to a local water source and:

- Assign small groups and their sampling materials and move the class to the stream.
- Have students collect organisms from the streambed in the riffles.
- Return to the classroom where groups will identify individual species in their sample and complete the "Stream Macroinvertebrate Inventory Report" (p. 6), then make a water quality determination based on the Total Index Value.
- Groups present their findings (based on their knowledge of tolerant and intolerant species) with a graph of tolerant/intolerant species per each testing site and determine overall stream quality. Students then brainstorm possible sources of pollution upstream from the testing location(s) and state an hypothesis.

Elaborate

This lesson is a very basic way to introduce biological testing to students. This lesson is designed to spark their interest. True biological testing is much more involved. Review and follow the basic protocol for biological testing (UAEX or OWW MATERIALS List p. 2).

Evaluate

Students will be evaluated in the field by their collection techniques and participation with their group.
Students will be evaluated in the class by their presentation and unit test.

Extensions

After discussion of outcome using BASIC sampling procedures, compare and contrast BASIC with the ADVANCED monitoring protocol, as presented in the NPS publication, which requires more exacting standards and greater technical skill for sampling. This is a small lesson that will mean more to students once chemical testing is introduced. This information leads to a study of watersheds and possibly Karst Topography. Riparian zone and its function are also connected to this activity.

BIOINDICATORS OF ENVIRONMENTAL HEALTH

The Beaver Lake Watershed is home to a variety of animal and plant species, many of which are "bioindicators" of the overall health of their surroundings. Variation in abundance, behavior, and wellbeing of bioindicator species can be a sign of changing environmental conditions. An understanding of how an organism functions in different environmental conditions, from clean to polluted, can help us learn more about the health of the habitat in which that animal, plant, or insect lives.



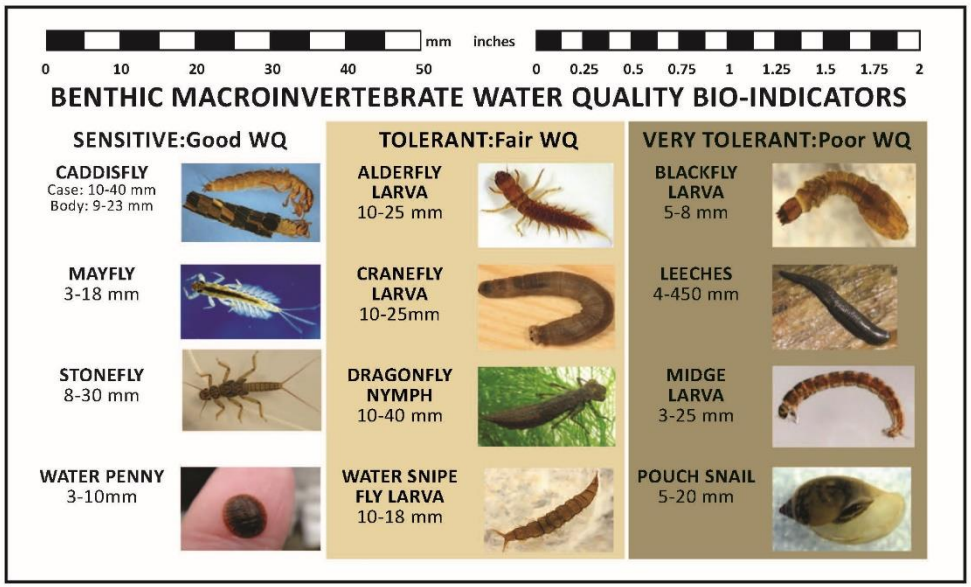



MACROINVERTEBRATES are organisms with no backbone or internal skeleton that are large enough to see without magnification. These organisms are very diverse and useful as bioindicators. They are a major food source for amphibians, birds, fish, and reptiles and an essential part of both aquatic and terrestrial food webs. As such, they are critical to the healthy function of field, forest, lake, stream, and wetland ecosystems.

Some macroinvertebrates are very **SENSITIVE TO POLLUTION**. They live and thrive only in the cleanest of environments or water of highest quality. Other species have greater tolerances to pollution that degrades living conditions or water quality.

AQUATIC SPECIES, that grow or live in or near water, are especially responsive to fluctuations in dissolved oxygen (DO), pH, temperature, salinity, turbidity (cloudiness caused by floating particles like algae, sediment, organic matter), and fertilizer or nutrient levels (nitrogen, phosphorous, potassium).

BENTHIC MACROINVERTEBRATE WATER QUALITY BIOINDICATORS



"BENTHIC" MACROINVERTEBRATES (aquatic worms, clams, crayfish, insects, and snails, for example) may spend all or only the immature (larval or nymph) stages of their life cycle attached to gravel, rocks, or plants at the bottom of water bodies. These bottom-dwelling organisms are grouped according to the different ways they feed and how they attach to surfaces. Feeding behaviors include filtering water for food, grazing on algae, or breaking down plant material that falls into the water, making nutrients available for other aquatic organisms. Some anchor to rocks and pebbles, while others attach to fallen leaves or twigs, or cling on sandy to muddy substrates.

STREAM MACROINVERTEBRATE INVENTORY REPORT

Site Name_____ **Date**_____

Site Number_____

Biological Data

Directions: **1) Place an x in the blank provided next to each macroinveterbrate identified in the field. 2) Add the number of x's found in each column and enter that number on the line next to "number of species found." (3) Multiply the sum by the Index Value (4) Add the 3 Index Values to get the TOTAL INDEX VALUE.**

*Aquatic invertebrate communities change with water quality. Overall water quality affects which types of organisms can survive in a body of water. These species of aquatic insects are separated by their tolerance levels to different types of water quality.

Sensitive Species	#	Somewhat Sensitive Species	#	Tolerant Species	#
Caddisfly Larvae:		**Beetle Larvae:**		**Aquatic Worms:**	
Dobsonfly/Hellgrammites:		**Clams:**		**Blackfly Larvae:**	
Mayfly Nymphs:		**Crane Fly Larvae:**		**Leeches:**	
Gilled Snails:		**Crayfish:**		**Midge Larvae:**	
Riffle Beetle Adult:		**Damselfly Nymphs:**		**Pouch Snails:**	
Stonefly Nymphs:		**Dragonfly Nymphs:**			
Water Penny Larvae:		**Scuds:**			
		Sowbugs:			
		Fishfly Larvae:			
		Alderfly Larvae:			
		Watersnipe Fly Larvae:			
Number of Sensitive Species Found:		Number of Somewhat Sensitive Species Found:		Number of Tolerant Species Found:	
*** times (x) 3= Index Value**		*** times (x) 2 = Index Value**		*** times (x) 1= Index Value**	
Index Value = _____		**Index Value =** _____		**Index Value =** _____	

TOTAL INDEX VALUE = _____

Excellent (> 22)_____ **Good (17-22)**_____ **Fair (11-16)**_____ **Poor (<11)**_____

For species not on the lists above write in here: _____

Please return this form to your Stream Smart representative along with your water samples.

Key to Macroinvertebrate Life in the River

(Sizes of illustrations are not proportional.)

Shells

Single Shell

- *spiral, opening on left* — **Pouch Snail**
- *spiral, opening on right* — **Gilled Snail**
- *coiled* — **Orb Snail**
- *conical* — **Limpet**

Double Shell

- *small, whitish, tan or brown* — **Pill or Fingernail Clam**
- *large, 2 to 8 inches, dark-colored* — **Freshwater Mussel**

No Shells

Legs

With Tentacles, Brushes or "Tails"

- *long breathing tube* — **Rat tailed Maggot Larva**
- *two fringed "tails"* — **Water Snipe Fly Larva**
- *smooth, "stiff," small head* — **Horse Fly Larva**
- *large, grey with tentacles* — **Crane Fly Larva**
- *white or grey with tentacles* — **Crane Fly Larva**
- *big "head," active* — **Midge Pupa**
- *black, attaches to hard surfaces* — **Black Fly Larva**

10+ Legs

- *lobster-like* — **Crayfish**
- *shrimp-like, swims on side* — **Scud or Amphipod**
- *walks on bottom* — **Aquatic Sowbug or Isopod**

Four Pairs of Legs

- *tiny, often brightly colored* — **Water Mite**
- *runs on top of water* — **Fishing Spider**

Three Pairs of Legs

Wings

Beetle-Like, Wings Hard

- *small, crawls on bottom* — **Riffle Beetle**
- *swims moving hind legs alternating* — **Water Scavenger Beetle**
- *back legs move at same time* — **Predaceous Diving Beetle**
- *swims on surface* — **Whirligig Beetle**
- *"Crawls" through water, spotted* — **Crawling Water Beetle**

Leathery Wings

- *tan, lives on surface* — **Marsh Treader**
- *dark, lives on surface* — **Water Strider**
- *grasping front legs, up to three inches* — **Giant Water Bug**
- *swims on back, back white* — **Backswimmer**
- *swims right-side-up, back black* — **Water Boatman**
- *long breathing tube, grasping front legs* — **Water Scorpion 'Nepa'**
- *long, stick-like* — **Water Scorpion 'Ranatra'**

No Wings

No Obvious "Tails"

- *brown, leatherlike, six legs, usually "C"-shaped* — **Riffle Beetle Larva**
- *six legs and prolegs on abdomen* — **Pyralid Caterpillar**
- *suction cup-like* — **Water Penny**
- *large body, hinged mouth* — **Dragonfly Larva**
- *green, tan, orange or white body* — **Caddisfly Larva**
- *lives in stone case* — **Caddisfly Larva**
- *lives in stick house* — **Caddisfly Larva**

One or Two "Tails"

- *dark head, green or tan body, two brush-like tails* — **Caddisfly Larva**
- *small, "spines" on side* — **Alderfly Larva**
- *large mouth parts, "spines" on side* — **Dobsonfly Larva**
- *"tails" long and stiff, long antennas* — **Stonefly Larva**
- *flat gills on abdomen* — **Mayfly Larva**
- *hangs from surface, large mouth parts* — **Predaceous Diving Beetle Larva**

Three "Tails"

- *long "tails," gills on abdomen* — **Mayfly Larva**
- *long "tails," gills on abdomen* — **Mayfly Larva**
- *large legs, feathery gills* — **Mayfly Larva**
- *plate-like "tails," no gills on abdomen* — **Damselfly Larva** (*side view of "tails"*)

Worm-Like

- *Suckers, expands and contracts, body segmented* — **Leech**
- *reddish brown, segmented body* — **Tubifex Worm**
- *glides along bottom, body not segmented* — **Flatworm or Planaria**
- *tan to brown, long* — **Horsehair Worm**
- *body with bristles, no suckers* — **Bristle Worm**
- *distinct head, red, green or tan, twists* — **Midge Larva**
- *small, hair-like, swims in "S" shape* — **Nematode or Threadworm**

Microscopic

- *apostrophe-shaped* — **Cyclops or Copepod**
- *round* — **Seed and Clam Shrimp**
- *swims with a jerk, using antennas* — **Water Flea or Daphnia**

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Izaak Walton League of America Aqua Bugs -

www.iwla.org/conservation/water/save-our-streams/aqua-bugs

PHOTO CREDITS

We are grateful to the following people and organizations who allowed us to use their images to help stream monitors ID their bugs.

Bob Hendricks

Black Fly larva

Black Fly larva

Caddisfly larva (with case)

Caddisfly larva

Caddisfly larva

Common Netspinning Caddisfly larva

Common Netspinning Caddisfly larva

Common Netspinning Caddisfly larva

Common Netspinning Caddisfly larva

Crane Fly larva

Damselfly larva

Damselfly larva

Dragonfly larva

Dragonfly larva

Dragonfly larva

Dragonfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Mayfly larva

Midge larva

Stonefly larva

Stonefly larva

Stonefly larva

Stonefly larva

Water Penny

Water Penny

Whirligig Beetle larva

Eileen Miller

Aquatic Sowbug

Aquatic Sowbug

Aquatic Worm

Crayfish

Fishfly larva

Flatworm

Flatworm

Gilled Snail

Leech

Scud

Watersnipe Fly larva

Great Swamp Watershed Association

Cranefly larva

Paul Havlinka

Crayfish

Insectimages.org/Colin van Overdijk

Freshwater shrimp

John Parke

Mussel

Clam

Lunged Snail

Missouri Department of Conservation

Alderfly larva

Alderfly larva

Aquatic Sowbug

Aquatic Worm

Black Fly larva

Black Fly larva

Caddisfly larva

Clam

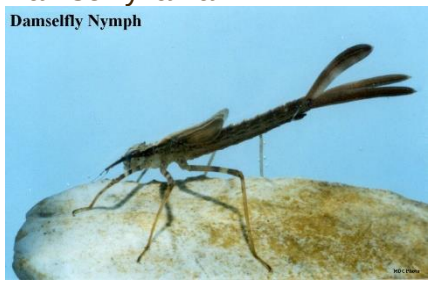
Common Netspinning Caddisfly larva

Common Netspinning Caddisfly larva

Cranefly larva

Cranefly larva

Damselfly larva



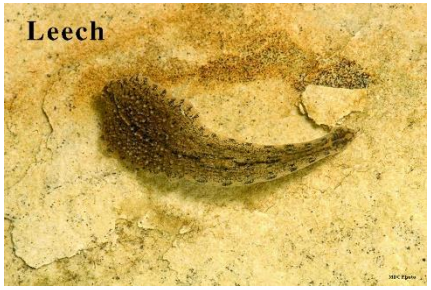
Damselfly larva

Dobsonfly larva

Fishfly larva

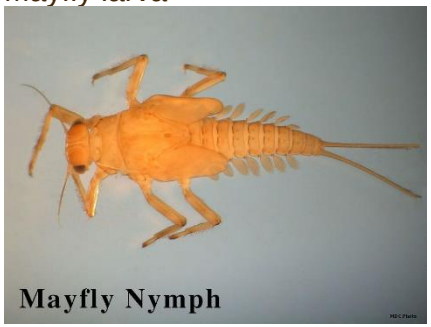
Gilled Snail

Leech



Mayfly larva

Mayfly larva



Midge Fly larva

Mussel

Riffle Beetle (adult)

Riffle Beetle (adult)

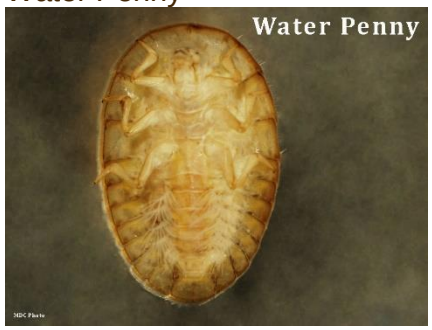
Riffle Beetle larva

Riffle Beetle larva

Scud

Stonefly larva

Water Penny



Watersnipe Fly larva

Troutnut

Alderfly larva

Alderfly larva

Caddisfly larva

Crayfish

Damselfly larva

Damselfly larva

Dobsonfly larva

Dobsonfly larva

Dragonfly larva

Dragonfly larva

Midge

Scud

Stonefly larva

Stonefly larva