Benthic Bugs and Bioassessment

Summary

Students investigate the relative water quality of a stream by conducting a simulated bioassessment by sampling aquatic macroinvertebrates (represented by ordinary materials).

Objectives

Students will:

- investigate the role that aquatic macroinvertebrates play in determining water quality.
- simulate the process of rapid bioassessment of aquatic macroinvertebrates.
- collect, sort, classify, identify, analyze, and evaluate a sample of materials representing aquatic macroinvertebrates.
- determine a stream's water quality using a pollution tolerance index based on a sample of aquatic macroinvertebrates.
- compare the differences between the relative water quality of different samples.

Materials

- *Copies of* ***Macroinvertebrate Identification Chart*** *Student Copy Page* (1 per group)
- *Copies of* ***Macroinvertebrate Data Sheets I*** *Student Copy Page* (1 per group)
- *Copies of* ***Macroinvertebrate Data Sheets II*** *Student Copy Page* (1 per group)
- *Copies of* ***Macroinvertebrate Data Sheets III*** *Student Copy Page* (1 per group)
- Materials for Bioassessment; similar objects may be substituted
- *Plastic tubs or storage bins for holding samples–dishpan size* (3)
- *Smaller plastic tubs–white* (3)
- *Aquarium nets–small, hand-held; can use hands or other scoop* (3)
- *Ice cube trays, petri dishes, or other sorting devices (cups)* (3)
- *Calculators* (3)
- Optional: *Water* (enough to fill the 3 sample tubs with at least 4 inches of water). *(Optional: coloring for the water so students cannot see the objects in the sample tub. Coloring options include dark food coloring; powdered chocolate milk mix to simulate sediment, tea bags to darken the water, powdered fruit drink mix, other.)*
- *Small paper clips* (100)
- *Large paper clips* (50)
- *Six different sizes, shapes, or colors of beads* (50 of each size/color/shape)
- *Pennies or other coins* (50)
- *Thin rubber bands* (50)
- *Thick rubber bands* (50)

Grade Level:
6–12

Subject Areas:
Biology, Environmental Science, Mathematics, Language Arts

Duration:
Preparation: 30 minutes

Activity: two 50 minute periods

Setting:
Classroom

Skills:
Interpret, Organize, Gather, Communicate

Vocabulary:
bioassessment, macroinvertebrate, biodiversity, benthic

Background

"The most direct and effective measure of the integrity of a water body is the status of its living systems" (Karr, 1998). One important way to determine the status of water's living systems is through biological assessment (bioassessment), which is the use of biological surveys and other direct measurements of living systems

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within a watershed. Aquatic macroinvertebrates (animals without backbones that live in aquatic environments and are large enough to be seen without the aid of a microscope or other magnification) are commonly monitored and are the basis of this activity.

Macroinvertebrates are valuable indicators of the health of aquatic environments in part because they are benthic, meaning they are typically found on the bottom of a stream or lake and do not move over large distances. Therefore, they cannot easily or quickly migrate away from pollution or environmental stress. Because different species of macroinvertebrates react differently to environmental stressors like pollution, sediment loading, and habitat changes, quantifying the diversity and density of different macroinvertebrates at a given site can create a picture of the environmental conditions of that body of water.

If exposed to an environmental stressor (e.g., pollution, warming due to low flows, low dissolved oxygen due to algal blooms, etc.), those macroinvertebrates that are intolerant to that stress may perish. Tolerant macroinvertebrates often inhabit the spaces left by the intolerant organisms, creating an entirely different population of organisms. For example, an unimpacted body of water will typically contain a majority of macroinvertebrates that are intolerant of environmental stressors, such as mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*), and Caddisflies (*Trichoptera*). A body of water that has undergone environmental stress may contain a majority of macroinvertebrates that are tolerant of these conditions such as leeches (*Hirudinea*), Tubifex worms (*Tubifex sp.*), and Pouch Snails (*Gastropoda*).

Bioassessments of macroinvertebrates are particularly helpful to biologists and others trying to determine the health of a river or stream. Bioassessment of macroinvertebrates is a procedure that uses inexpensive equipment, is scientifically valid if done correctly, and can be conducted by students. Bioassessments can provide benchmarks to which other waters may be compared and can also be used to define rehabilitation goals and to monitor trends. Trend monitoring is a common application of bioassessment by students groups and others involved in water quality monitoring.

Collecting, identifying, and quantifying macroinvertebrates are the initial steps in a bioassessment. The next step involves using formulas to calculate the relative water quality based on the diversity and quantity of the sampled organisms. These formulas, called metrics, relate the numerical diversity and density of organisms to a water quality rating. The most common metrics are the EPT/Midge Ratio and the Pollution Tolerance Index.

The EPT/Midge Ratio metric compares the total number of intolerant organisms, specifically the E.P.T—***Ephemeropterans*** (mayflies), ***Plecopterans*** (stoneflies), and ***Trichopterans*** (caddisflies)—with the total number of tolerant organisms, specifically *Chironomids* (midges). Typically the higher the number of intolerant organisms, the better the water quality.

The Pollution Tolerance Index assigns a numerical value to each macroinvertebrate order, with the higher numbers assigned to pollution intolerant organisms, and decreasing numbers assigned to increasingly pollution tolerant organisms. The scores are totaled and compared with a water quality assessment scale to yield a relative water quality rating for the sample.

To gather the best quality and most usable data, the Environmental Protection Agency (EPA) recommends that biological sampling of macroinvertebrates be conducted in ways that minimize year-to-year variability. To accomplish this, biologists tend to sample for at least one week during the same season(s) each year. Additionally, sampling is conducted when sites are easily accessible and the number of organisms is high. This usually occurs in the spring after the ice has broken and late-stage larvae are present, or in the late fall when organisms are more mature.

While bioassessments are extremely important in and of themselves, they

are most useful when combined with chemical and habitat assessments. "Biosurvey techniques, such as the Rapid Bioassessment Protocols, are best used for detecting aquatic life impairments and assessing their relative severity. Once an impairment is detected, however, additional ecological data, such as chemical and biological (toxicity) testing is helpful to identify the causative agents, its source and to implement appropriate mitigation" (EPA, 1991).

Warm Up

1. Ask students to define the term "aquatic macroinvertebrate" (invertebrates that live in streams, rivers, lakes, or ponds that are large enough to be seen without the aid of a microscope or other magnification).
2. Have them list examples of aquatic macroinvertebrates (e.g., leeches, mayflies, snails, dragonflies, etc.), and their role in the food web of a stream.
3. Divide students into three groups and distribute copies of the ***Macroinvertebrate Identification Chart*** to each group. Instruct them to complete the middle (Looks Like) column of this sheet by researching aquatic macroinvertebrates on the Internet, in resource books, or in this guide (the activity "Invertebrates as Indicators" has invertebrate pictures). The North American Benthological Society maintains a Web site with links to various state and regional aquatic macroinvertebrates at www.benthos.org. Students will use this sheet in the bioassessment activity. *Option: To save time, you may complete the information in the chart for them.*
4. Briefly explain to the students that aquatic macroinvertebrates are used as indicators of the relative health of a stream, and that the common form of sampling them is called a bioassessment, which they will conduct in this activity.

The Activity

1. Inform students that they will be simulating a bioassessment of a stream using ordinary objects to represent macroinvertebrates.

2. Set up three sets of collecting stations (see illustration below), each containing the following: stream sampling site (see directions in Step 2), collection bucket, sorting trays, the ***Macroinvertebrate Identification Chart,*** *and* ***Macroinvertebrate Data Sheets I, II, and III.***

Hellgrammites are used as water quality indicators. Courtesy: Richard Fields, Outdoor Indiana *Magazine*

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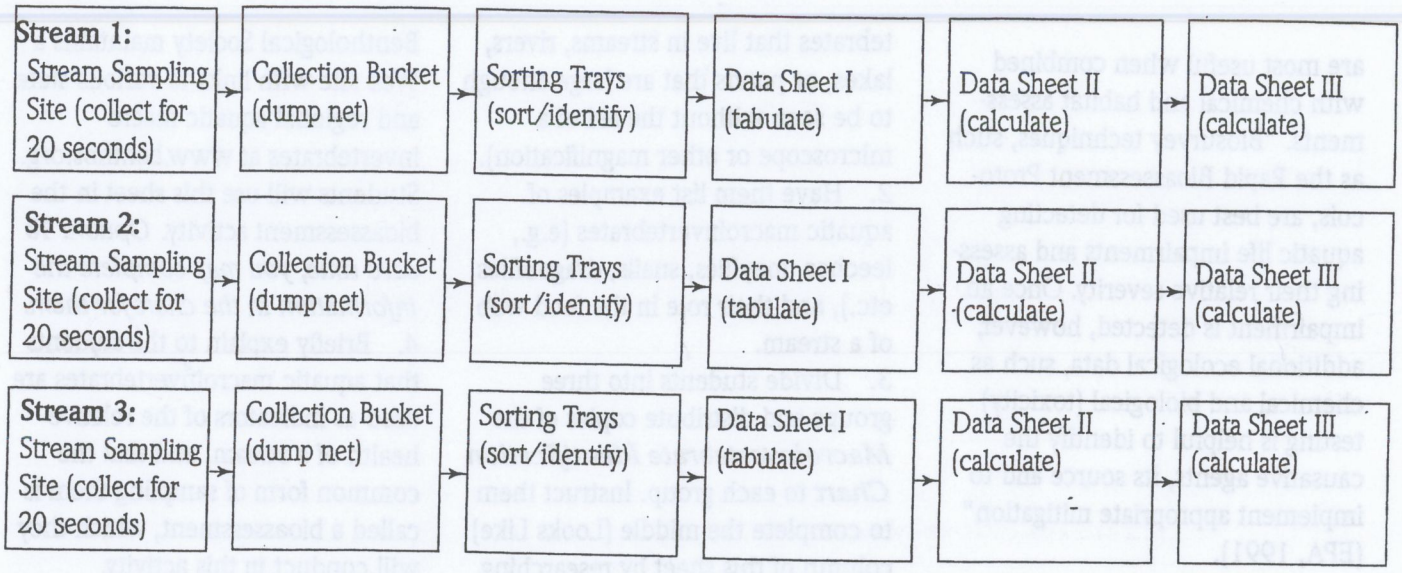

3. **Optional: For the stream sampling sites: fill three large plastic storage bins with four inches of water and label them Stream 1, 2, and 3.** *(Optional–add coloring to the water until objects on the bottom are not clearly seen).*
4. **Place objects representing macroinvertebrates in the three tubs according to the following chart:**

Macroinvertebrate	Represented by:	Number of Items per Sample			Total Items
		Stream Sample 1	Stream Sample 2	Stream Sample 3	
Mayflies	Yellow beads	35	15	0	50 beads
Stoneflies	Small paper clips	65	35	0	100 clips
Dobsonflies	Large paper clips	30	20	0	50 clips
Caddisflies	Red beads	30	20	0	50 beads
Craneflies	White beads	25	13	12	50 beads
Dragonflies	Green beads	20	20	10	50 beads
Scuds	Black beads	5	15	30	50 beads
Midges	Blue beads	0	20	30	50 beads
Leeches	Thick rubber bands	0	15	35	50 bands
Pouch Snails	Pennies	0	15	35	50 pennies
Tubifex Worms	Thin rubber bands	0	15	35	50 bands

5. Divide students into three groups. Assign students within each group to one of the following five tasks: stream sampling, sorting at the collection bucket, counting/recording at *Macroinvertebrate Data Sheet I,* and calculating/evaluating at *Macroinvertebrate Data Sheets II and III.*

6. Instruct students to simulate a rapid bioassessment at their stream sampling site as follows:

a. **Using an aquarium net, the students at the site have *twenty seconds* to collect as many macroinvertebrates (paper clips, beads, etc.) from the stream as possible.** They should place the macroinvertebrates in the collection bucket.

b. **Students at the collection bucket then sort the collected macroinvertebrates into like categories based on the *Macroinvertebrate Identification Sheet* and place them in the ice cube tray or cups.** For example, they should place all of the mayflies into one cube, caddisflies into another, etc.

c. **The students using the *Macroinvertebrate Data Sheet I* tabulate the sorting results onto the data sheet and calculate the percent composition of each macroinvertebrate in the stream site.**

d. **The students using *Macroinvertebrate Data Sheet II* take the data from *Macroinvertebrate Data Sheet I* to calculate the EPT/Midge ratio.**

Students conducting a bioassessment on a local stream. Courtesy: Richard Fields, Outdoor Indiana *Magazine*

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e. **The students with *Macroinvertebrate Data Sheet III* use the data from *Data Sheet I* to complete the Pollution Tolerance Index to determine their Water Quality Assessment score for their stream sample.**

7. **Have students compare their results with the other groups. What were the similarities and differences between the three sites?** Which stream had the highest level of water quality? The lowest?

Wrap Up

Have students write a paragraph that describes their stream based on the macroinvertebrate sample they collected. If they sampled an impaired stream they should describe the habitat, address possible pollution sources, and give other pertinent details. Allow them to be creative.

Ask students what they think of this type of scientific sampling process. Do students feel that they could use this same process to perform a bioassessment in an actual stream? Did their samples accurately reflect the population of invertebrates in their stream? How do they know? Ask students to brainstorm how the process could be modified to increase its accuracy (e.g., conduct the sampling three times for each stream and compare or average the results)?

Have them identify positive and negative aspects of this type of sampling. For example, do they believe that they netted larger insects more easily than smaller insects? Can such biased sampling occur in an actual rapid bioassessment of invertebrates?

Assessment

Have students:

- investigate the role that aquatic macroinvertebrates play in determining water quality (***Warm Up***).
- simulate the process of rapid bioassessment of aquatic macroinvertebrates (**Steps 5 and 6**).
- collect, sort, classify, identify, analyze, and evaluate a sample of materials representing aquatic macroinvertebrates (**Step 6**).
- determine a stream's water quality using a pollution tolerance index based on a sample of aquatic macroinvertebrates (**Step 6**).
- compare the differences between the relative water quality of different samples (**Step 7**).
- interpret water quality data to develop a description of a stream (***Wrap Up***).

Extensions

Have students conduct an actual rapid bioassessment of a local stream or lake. Ask a local biologist to assist in the assessment, or contact your local watershed monitoring group to see if students can help with a local monitoring project.

Have students locate specific aquatic macroinvertebrate identification keys for their watershed, state, or region. Research the pollution tolerance, habitat, and regional distribution of the individual species. The North American Benthological Society maintains a Web site with links to various state and regional aquatic macroinvertebrates at www.benthos.org.

Resources

Fore, L. 1998. *Field Guide to Freshwater Invertebrates.* http://www.seanet.com/~leska/Online/about_guide.html.

Freshwater Benthic Ecology and Aquatic Entomology Homepage. 1999. http://www.chebucto.ns.ca/Science/SWCS/ZOOBENTH/BENTHOS/benthos.html

Karr, J., and E. Chu. 1998. *Restoring Life in Running Waters: Better Biological Monitoring.* Washington, D.C.: Island Press.

Mitchell, M., and W. Stapp. 1997. *Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools.* Dubuque, IA: Kendall/Hunt Publishing Co.

Save Our Streams (SOS) Stream Study. 1999. http://www.people.virginia.edu/~sos-iwla/Stream-Study/StreamStudyHomePage/StreamStudy.HTML

United States Environmental Protection Agency (EPA). 1991. *Rapid Bioassessment Protocols (RBPs) for use in Streams and Wadeable Rivers.* http://www.epa/gov/owow/monitoring/rbp/

Macroinvertebrate Identification Chart

Macroinvertebrate	Looks like... (draw the invertebrate here)	Represented by... (for example beads, coins, etc.)
Mayflies (Order *Ephemeroptera*)		
Stoneflies (Order *Plecoptera*)		
Caddisflies (Order *Trichoptera*)		
Dobsonflies (Order *Megaloptera*)		
Midges (Order *Chironomidae*)		
Craneflies (Order *Diptera*)		
Dragonflies (Order *Odonata*)		
Scuds (Order *Amphipoda*)		
Pouch Snails (*Class Gastropoda*)		
Tubifex Worms (Class *Oligochaeta*)		
Leeches (Class *Hirudinea*)		

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Macroinvertebrate Data Sheet I

Stream #:

Recorded by:

Date of Sampling:

Percent Composition of Major Groups:

After the macroinvertebrates are sorted, tabulate the number of organisms for each of the major groups listed below and calculate their percent composition. This measure yields the relative abundance of macroinvertebrates within your sample.

Percent Composition=Number of Organisms in Each Group / Total Number of Organisms

Macroinvertebrates	Number of Organisms in Each Group	Percent Composition
Mayflies (Order *Ephemeroptera*)		
Stoneflies (Order *Plecoptera*)		
Caddisflies (Order *Trichoptera*)		
Dobsonflies (Order *Megaloptera*)		
Midges (Order *Chironomidae*)		
Craneflies (Order *Diptera*)		
Dragonflies (Order *Odonata*)		
Scuds (Order *Amphipoda*)		
Pouch Snails (Class *Gastropoda*)		
Tubifex Worms (Class *Oligochaeta*)		
Leeches (Class *Hirudinea*)		
Total Number of Organisms		

(Adapted from Mitchell, 1997)

Student Copy Page

Macroinvertebrate Data Sheet II

Stream #: _____

Recorded by: _____

Date of Sampling: _____

EPT/Midge Ratio

1. Using the total number of macroinvertebrates from *Data Sheet I*, add up the total number of EPT individuals: Mayflies (*Ephemeroptera*) Total # _____
   Stoneflies (*Plecoptera*) Total # _____
   Caddisflies (*Trichoptera*) Total # _____
   Total # (E+P+T) = _____

2. Add up the total number of Midges (*Chironomidae*)
   Total # Midges _____

3. Divide the total number of EPT individuals by the number of midges to determine the
   EPT/Midge Ratio = _____

4. Generally speaking, the larger the number of individuals in the EPT categories, the better the water quality. Therefore, the higher the final value of the ratio, the better the water quality.

EPT/Midge Ratio Formula:

$$\frac{\text{Total Number of EPT Individuals}}{\text{Total Number of Midge (}\textit{Chironomidae}\text{) Individuals}} = ____ =$$

Example 1: $\frac{\text{Total EPT}}{\text{Total Midges}} = \frac{100}{10} = 10$

Example 2: $\frac{\text{Total EPT}}{\text{Total Midges}} = \frac{40}{10} = 4$

Discussion:
The EPT/Midge Ratio of Example 1 is higher than Example 2; therefore the relative water quality is better in Example 1 than in Example 2.

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Macroinvertebrate Data Sheet III

Pollution Tolerance Index

1. Place a check next to each macroinvertebrate group present in your sample. For example, whether you found one mayfly or fifty mayflies, place one check next to the mayfly line in Group 1.
2. Complete the chart for all of the macroinvertebrate groups.
3. Calculate the group scores using the multipliers provided.
4. Total all of the group scores for your Total Score.
5. Compare your Total Score with the Water Quality Assessment Chart scores and record the relative water quality rating for your stream sample.

Stream #:_____
Recorded by:_____
Date of Sampling:_____

Group 1 Macroinvertebrates: Very Intolerant	Group 2 Macroinvertebrates: Intolerant	Group 3 Macroinvertebrates: Tolerant	Group 4 Macroinvertebrates: Very Tolerant
_____Stoneflies _____Mayflies _____Caddisflies _____Dobsonflies _____Dragonflies	_____Dragonflies _____Scuds _____Craneflies	_____Midges _____Leeches	_____Pouch Snails ____Tubifex worms
# of checks = ____ x 4 Group Score=____	# of checks =____ x 3 Group Score=____	# of checks =____ x 2 Group Score=____	# of checks =____ x 1 Group Score=____
Total Score = _____ Your Water Quality Assessment:		Water Quality Assessment Chart: ≥23 Potentially Excellent Water Quality 17-22 Potentially Good Water Quality 11-16 Potentially Fair Water Quality ≤10 Potentially Poor Water Quality	

(Adapted from Mitchell, 1997)

Macroinvertebrate Data Sheet IV

Stream # _____

Recorded by: _____

Date of Sampling: _____

Simpson's Diversity Index

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

Where 0 =no diversity 1 = infinite diversity

D = diversity index

N = total number of individuals (of all species) in the sample

n = number of individuals of each species in the sample

Macroinvertebrates	# of Organisms in Each Group (n)	n(n-1)
Mayflies		
Stoneflies		
Caddisflies		
Dobsonflies		
Midges		
Craneflies		
Dragonflies		
Scuds		
Pouch Snails		
Tubifex worms		
Leeches		
TOTAL	N=	$\sum$ n(n-1) =

Macroinvertebrate Data Sheet IV

Stream # _____

Recorded by: _____

Date of Sampling: _____

Simpson's Diversity Index

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

Where 0 =no diversity 1 = infinite diversity

D = diversity index

N = total number of individuals (of all species) in the sample

n = number of individuals of each species in the sample

Macroinvertebrates	# of Organisms in Each Group (n)	n(n-1)
Mayflies	1	1(1-1) = 0
Stoneflies	3	3(3-1) = 6
Caddisflies	5	5(5-1) = 20
Dobsonflies	0	0(0-0) = 0
Midges	6	6(6-1) = 30
Craneflies	1	1(1-0) = 0
Dragonflies	3	3(3-1) = 6
Scuds	6	6(6-1) = 30
Pouch Snails	6	6(6-1) = 30
Tubifex worms	8	8(8-1) = 56
Leeches	5	5(5-1) = 20
TOTAL	N= 44	$\sum$ n(n-1) = 198

$D = 1 - \left(\frac{198}{44(43)}\right)$

$= 1 - \left(\frac{198}{1892}\right)$

$= 1 - .1047$

$D = .8953$

∴ High Diversity