Teacher's Guide

Introduction to the Biotic Water Quality of a Stream

Lesson Description

This lesson allows students to learn the Biotic Water Quality Score (BWQS) method for collecting macroinvertebrates. Organisms with a high sensitivity to reduced oxygen levels are given a high numerical value. Organisms that can thrive in low oxygen levels are given a low numerical value. Factors that promote high oxygen content will also promote a diversity of macroinvertebrates. The central idea behind quantification is that macroinvertebrates have a wide range of oxygen requirements.

Following student research on assigned benthic, aquatic organisms, the preliminary activity will allow students to perform a "dry run" to practice the skills needed for the actual BWQS field study. Skills included are: collecting procedures, proper identification of aquatic organisms, using a taxonomic key, data recording and evaluation. The preliminary activity in the classroom consists of showing the students the kick seine net and demonstrating how to use it. A key idea is to put down four meter sticks to show students the size of the area they should be disturbing. Students will learn that "kicking" is turning over rocks and mixing up the sediment with their feet as well as rubbing the benthic organisms to dislodge them from the bottom of the rocks. After these skills are demonstrated, students in small groups use the sheets from their student packets to identify the various groups of aquatic organisms. Students use a picture and/or taxonomic key to identify each organism and then tally all organisms on the BWQS data sheet. Using MS Excel, students create a spreadsheet with the appropriate biotic values for each organism. Using this spreadsheet they then calculate the BWQS. See www.projectwatershed.org for details.

Following the procedure, three samples are collected from the stream study site. Each kick seine collection must be scanned carefully to find all the organisms. Usually an attempt is made to collect 100 organisms for the purpose of having a representative sample. Be aware that the larger more motile organisms will be collected first. Teachers will demonstrate how to carefully move debris and search for the less motile macroinvertebrates. Give students the opportunity to use the same techniques to continue the search. With continued supervision and patience the smaller, less motile organisms will be collected.

Sometimes students collect far fewer aquatic macroinvertebrates than the expected numbers. In this case, it is easy to express the number of organisms collected as a percentage of 100. In a small population, each organism must be represented in the final BWQS. Find the spreadsheet from the Project Watershed website, with all formulas included, under teacher resources. If you are unable to download the spreadsheet from the website, the BWQS sheet included in this packet will have to be calculated by students.

Science Concepts Introduced

- Sampling procedures
- Macroinvertebrate identification
- Determination of species diversity
- Observation of macroinvertebrates life cycles

Process Skills Emphasized

- Collecting benthic organisms
- Using a taxonomic key
- Organizing
- Analyzing data into a spreadsheet using MS Excel to determine the BWQS.
- Use an MS-Excel spreadsheet to analyze and graph data.

Technology Used

- Internet
- Word and Excel programs
- Project Watershed database
- Aquatic macroinvertebrate picture keys: www.iwla.org
- www.dec.state.ny.us/website/dow/stream/index.htm

MST Standards

- Standard 1 – key idea 1 and 3
- Standard 4 – key idea 6 and 7
- Standard 7 – key idea 1

Learning Outcomes

Students will be able to:

- Properly use a taxonomic and/or picture key to identify benthic organisms
- Collect aquatic macroinvertebrates using a kick seine net
- Enumerate all organisms collected
- Compute a BWQS based on a collection of macroinvertebrates
- Graphically represent each group of the organisms that make up the BWQS
- Use the Project Watershed database to compare BWQS to the chemical and physical properties of a stream.

Time Requirements

- Preparation activity - two class periods (60 – 80 minutes)
- Data collection – 30 - 40 minutes (approximately) at a stream site.
- Data Analysis - two-class period (60 – 80 minutes) in the computer lab

Instructional Strategies

- Collection and identification of macroinvertebrates
- Enumeration of macroinvertebrate on a spreadsheet.
- Group research, followed by presentations

Background

Research on Macroinvertebrates

Nerbonne (2003) found a possible bias and error in sorting and identifying aquatic insects (macroinvertebrates). In a masters thesis she described students, when sorting insects from debris (kick seine,) selected mostly larger (rather than smaller) insects and insects that moved slowly (compared to insects that moved too fast or not at all). Proper insect identification was also a problem. Nerbonne's study shows the need for adequate training and preparation. She also suggests that sampling groups work in teams for sorting and identifying aquatic macro-invertebrates to verify students sorting and identification efforts.

Prior to the field trip, knowledge of the stream site and weather conditions is a necessity for the safety of the students. Even smaller streams can be dangerous with fast, high waters.

Project Watershed has a permit, and all schools involved are collecting under the Project Watershed umbrella. Project Watershed has a collection license that will support your activities only while collecting with them.

The handouts of macroinvertebrates from the Project Watershed site (see teacher resources) that represent the collections for the classroom simulation are in the student packet. The macroinvertebrate collection key is in the teacher packet. This preliminary activity will allow students to become familiar with the collecting equipment, collecting procedures, identification of macroinvertebrates, data recording and the calculation of the BWQS.

Preliminary Activity

Teachers should have a basic understanding of the aquatic macroinvertebrate life cycles and also be able to identify (or use a key to identify) most of the aquatic insects on the data table. Chemical and physical needs of aquatic organisms are important to know because of the relationship between those parameters and the number and types of aquatic organisms.

Students will perform a classroom simulation of the stream collection process before going to the stream for the actual field collection process. Each time they will follow the same procedure as seen in the SUNY ESF Lesson #5 Biological Stream Monitoring: How to Calculate the Biotic Water Quality Score. Collect aquatic macroinvertebrates, properly identify them and input the values into a spreadsheet to determine the BWQS.

Stream Data Collection

Students must be supervised while in or near the stream performing the collection procedures. Assume that at least 10 different groups of benthic organisms could be identified. Then from their simulation they will be able to separate all similar organisms into separate containers. Once they have scanned the kick seine after three different collections a final tally of each container will be conducted. The students then record the final number of each different type of organism and record the data on the tally sheet. Carefully release all organisms back into the stream. Collect all equipment and prepare to exit the stream site leaving it as clean as when you arrived.

Assessment

Assessment of this lesson is two fold. First, the preliminary student activity can be assessed by which stream site each group is performing. Teachers have the data answer sheet to check student's results. Each group will receive stream site sheets numbered 1 thru 5. The results should be the same from group to group when using the sample stream site. Second, after data is collected in the field it must be analyzed. Students will analyze each set of data collected to input the BWQS. Students will use the Project Watershed spreadsheet from the teacher resource section on the website to analyze their data.

Extensions/Options

- This same activity can be done using one stream site and comparing the BWQS from season to season.
- Research the life cycles of aquatic organisms; this will promote understanding of how aquatic ecosystems can change from season to season. Groups of 2 or 3 can research specific organisms and present to the class pictures of juveniles and adults and their ecological role at various stages of their metamorphosis.
- Project Watershed's database can be used to download the data for graphing the water chemistry at the site where students have collected invertebrates. Compare the chemical and physical properties of all highly sensitive (a high BWQS value) stream collection sites to the same properties of low sensitivity sites (a low BWQS value). Report the similarities and differences in your findings to the class.
- Analyze the similarities or differences in the BWQS in fall, winter, spring and summer collections.
- Draw relationships between abiotic (chemical and physical) properties and biotic properties.

Key Terms

abiotic, aquatic organisms, benthic, biotic, chemical and physical parameters , cobbles, diversity, nymph, larva, macroinvertebrates, life cycles, runoff, stream ecosystems, riffles, pools.

Prerequisite Knowledge

- basic understanding of stream ecology
- use of taxonomic dichotomous keys of macroinvertebrates
- use of taxonomic dichotomous picture keys of macroinvertebrates
- Microsoft Word and Excel
- aquatic life cycles
- pollution ecology of runoff in streams
- runoff
- nonpoint source pollution
- point source pollution

Equipment Needed

- aquatic kick seine net
- white board or white background
- light colored collecting pans and jars (10 – 12)
- forceps and plastic spoons (6 – 8 of each)
- boots or waders (2 or 3 pairs)
- taxonomic and picture keys (4 or 5 laminated)

References

Biological Stream Monitoring: How To Calculate the Biotic Water Quality Score, Lesson 5 on invertebrates monitoring can be downloaded from the SUNY ESF website. Follow these links:

1. www.esf.edu/outreach/
2. K-12 teachers & students
3. K-12 programs and resources
4. Supplemental curriculum materials and other resources
5. Environmental analysis of watersheds

See Key from Project Watershed for identification of macroinvertebrates.

M.K. Mitchell and W.B. Stapp 1997 Field Manual for Water Quality Monitoring, GREEN/Earth Force, Alexandria, VA.

Websites

- Project Watershed Database: www.projectwatershed.org
- Aquatic Macroinvertebrate picture keys: www.iwla.org
- www.dec.state.ny.us/website/dow/stream/index.htm

Work Cited:

Caduto, Michael J., 2003 Canaries of the Waters, Sanctuary, Massachusetts Audubon Society, p. 11 – 13.

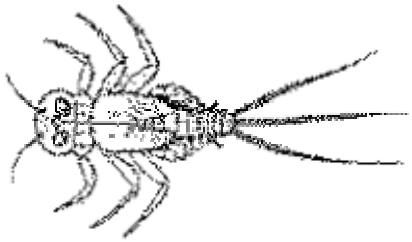
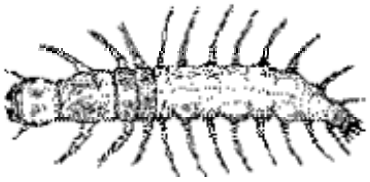
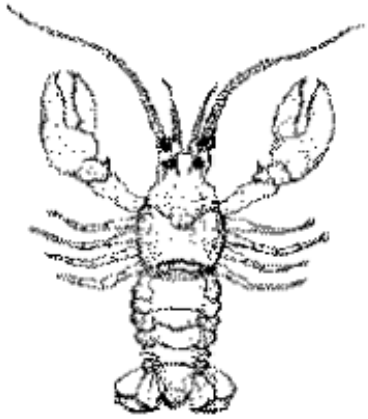
Nerbonne, Julia Frost and Bruce Vondracek. 2003. Volunteer Macroinvertebrates Monitoring: Assessing Training Needs Through Examining Error And Biases In Untrained Volunteers, Journal of the North American Benthological Society 22 (1): 152 – 163.

Handouts

1. Data collection sheets from the Project Watershed website. www.projectwatershed.org
2. Each Stream Study (1-5) is based on material found on the Project Watershed web site.
3. Spreadsheets for sample collections of the BWQS.

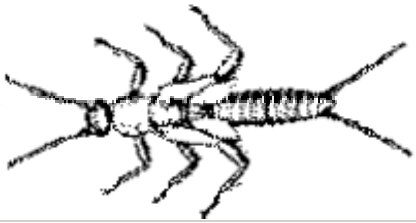
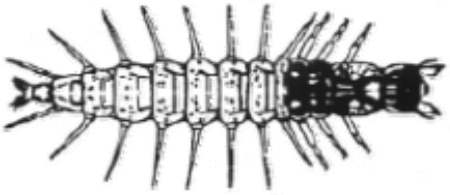
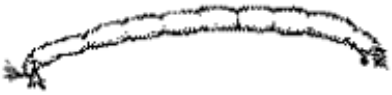
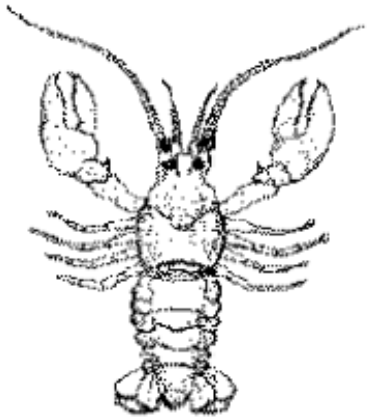
Sample 1 BWQS Answer Page

Total points = 372/40 = 93 Biotic Water Quality Score = Excellent

10 Stonefly nymph x 10 points =100 	10 Mayfly nymph x 10 points = 100 
4 Caddisfly larva x 10 points = 40 	2 Water Penny larva x 10 points = 20 
6 Dobsonfly larva x10 points = 60 	2 Riffle Beetle larva x 10 points= 20 
4 Crayfish x 6 points = 24 	2 Gilled Snail x 4 points = 8 

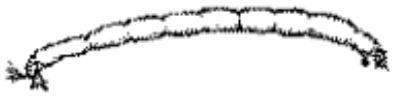
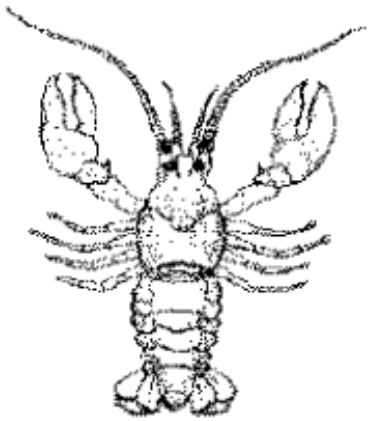
Sample 2 BWQS Answer Page

Total points = 174/32 = 54 Biotic Water Quality Score = Good

2 Stonefly nymph x 10 points = 20 	3 Fishfly larva x 6 points = 18 
1 Caddisfly larva x 10 points= 10 	1 Water Penny larva x 10 points = 10 
2 Cranefly larva x 8 points = 16 	14 Midgefly larva x 5 points = 70 
2 Crayfish x 6 points = 12 	4 Aquatic worm x 0 points = 0 

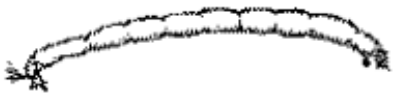
Sample 3 BWQS Answer Page

Total points = 108/19 = 56 Biotic Water Quality Score = FAIR

2 Dobsonfly larva x 10 points x 20 	2 Stonefly nymph x 10 points = 20 
4 Midgefly larva x 5 points = 20 	5 Crayfish x 6 points = 30 
3 Aquatic worm x 0 points = 0 	3 Damselfly nymph x 6 points = 18 

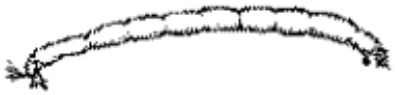
Sample 4 BWQS Answer Page

Total points = 129/28 =46 Biotic Water Quality Score = POOR

2 Leech x 2 points = 4 	2 Cranefly larva x 8 points = 16 
4 Aquatic worm x 4 points = 0 	5 Midgefly larva x 5 points = 25 
3 Lunged snail x 4 points = 12 	12 Blackfly larva x 6 points = 72 

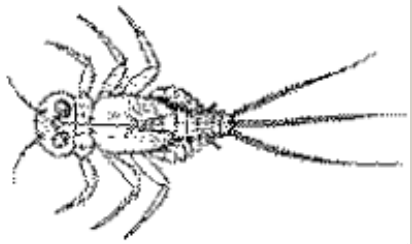
Sample 5 BWQS Answer Page

Total points = 166/47 = 35 Biotic Water Quality Score = POOR

15 Aquatic worm x 0 points = 0 	9 Blackfly larva x 6 points = 54 
3 Lunged snail x 4 points = 12 	20 Midgefly larva x 5 points = 100 

Sample 6 BWQS Answer Page

Total points =322/36 = 89 Biotic Water Quality Score = EXCELLENT

7 Mayfly nymph x 10 points =70 	2 Cranefly larva x 8 points = 16 
8 Caddisfly larva x 10 points = 80 	1 Planarian x 0 points = 0 
4 Gilled snail x 4 points =16 	10 Stonefly nymph x 10 points = 100 
2 Dobsonfly larva x 10 points = 20 	2 Water Penny larva x 10 points = 20 

Student's Guide

Introduction to the Biotic Water Quality of a Stream

Introduction

Aquatic insects are like canaries in the coal mine. They indicate the health of the water. Each aquatic species has certain tolerances to pollution levels. Insects can be affected by changing water chemistry, temperature, dissolved oxygen, substrate and water flow. A clean environment has a diversity and richness of aquatic insects (Caduto, 2003).

Pollution of a stream can come from many different sources. Water that passes through a heavily residential area faces runoff from lawn chemicals and fertilizers, sewage treatments outflows, and leaching of septic systems. In a rural area, most of the contamination comes from runoff from farms containing high amounts of nitrogen and phosphorus (Caduto, 2003). All types of runoff have the potential to harm an aquatic ecosystem. If runoff kills algae on rocks, then mayflies that feed on the algae die off. The stoneflies and others that feed on the mayflies soon die off and eventually affect the top predators such as trout.

In a coal mine when a canary died, the miners got out of the mine quickly. If the insects and other macroinvertebrates die in our streams, what can we do? Where can we go? Our job is to use macroinvertebrates as indicators of stream health to tell us if there are pollution problems in the stream or watershed. A wide diversity of oxygen sensitive macroinvertebrates in a stream equates to a healthy canary in a coal mine.

Learning Outcomes

Students will be able to:

- Properly use a taxonomic and picture key for aquatic macroinvertebrates.
- Collect aquatic macroinvertebrates using a kick seine net.
- Graphically represent the Biotic Water Quality Score (BWQS) and compare water quality conditions at the site at various seasons of the year.

Skills Required

- Group work in a cooperative manner
- Using a taxonomic key (proper macroinvertebrate identification)
- Proper sampling procedures
- Data collection and analysis
- Spreadsheet composition (data entry and analysis)

New Terms

abiotic, aquatic organisms, benthic, biotic, chemical and physical parameters , cobbles, diversity, nymph, larva, macroinvertebrates, life cycles, runoff, stream ecosystems, riffles, pools.

Quest
We are making a transition from our current biotic monitoring method to a more quantified method for Biotic Water Quality Score (BWQS). Your quest is to find a way to improve the biotic method by using the BWQS.

You will include a section in your final report offering suggestions for improvement. All aspects of biotic monitoring are open for suggestions. If something about the process described in the lesson is unclear to you, define the problem and suggest a possible improvement. Suggestions will go to your teacher and to the Project Watershed host site. If you are uncertain what the suggestion for improvement should be, at the very least explain what you are having difficulty understanding. We will make every attempt to help you in your quest.

Materials
- aquatic kick seine net
- white board or plastic about the size of a kick seine (2' x 3')
- light colored collecting pans and jars (10 – 12)
- forceps and plastic spoons (6 – 8 of each)
- boots or waders (2 or 3 pairs)
- taxonomic and picture keys (4 or 5 laminated)
- data tables

Procedure
Research on macroinvertebrates
1. Students work in pairs or small groups.
2. Each group will be given a specific aquatic organism.
3. Each group will be responsible for gathering as much information on that organism and presenting it. This can be done using poster board or power point.
4. Presentations should include information for each stage of nymph, larva and the adult. Include: a picture, physical descriptions, changing habitats, scientific name, role in the food web, use as an indicator species and any human uses.

Preliminary Lesson
1. In small groups you will each receive a packet containing pictures of benthic organisms from an actual stream sample.
2. Your group task is to correctly identify all presorted organisms.
3. Make sure everyone in the group agrees. Identification is a team effort, not the job of one student (group checks and balances).
4. Record the numbers for each macroinvertebrate next to its name in the spreadsheet.
5. The last step is to calculate the BWQS for that stream site using the values in the spreadsheet.

Stream Data Collection
You will be collecting macroinvertebrates from a specific section of a stream and determining the BWQS for that section. The BWQS may not be indicative of the entire stream because of many other factors. Discuss with your group why and how these numbers can change from section to section of the stream.
1. In groups, pick a shallow area (1'– 2') in a riffle near the study site. The sample area should have plenty of cobbles (rocks).
2. Samples should be taken as demonstrated by your teacher in class. It is very important samples are gathered as carefully as possible to obtain a representative sample of the macroinvertebrates living in the stream.
3. The collecting group will split into 2 sub-groups. The kickers (2 students) and the collectors (4 or 5 students). Students can switch from time to time.
4. A 3' by 3' area should be sampled (kicked) for 1 minute.

5. The kick seine should be carefully brought to the stream bank and placed on a white background (for better visibility).
6. Three or four students should check the net for macroinvertebrates. Students should be thorough and take their time.
7. Carefully remove these organisms and place all similar organisms in a container with water.
8. After all macroinvertebrates have been collected, they need to be identified accurately. Every member of the collecting team needs to help. All decisions need to be verified by another member of the team (a system of checks and balances).
9. Record your data on the data sheet. The BWQS can be calculated from the data sheet.

Extensions/Options

Prepare a presentation of your stream study data at a public forum. Using either poster board or power point, present your sampling methods, data collected and analysis of the water quality. You may hypothesize on why the stream supports this type of diversity and describe why projects like this have an important place in environmental monitoring.

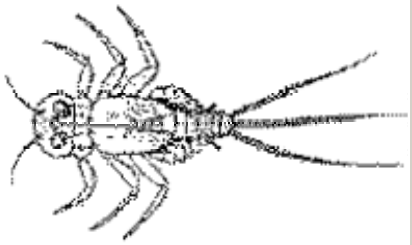
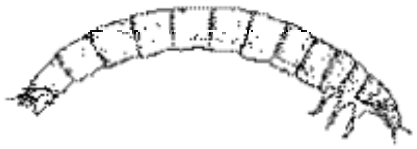
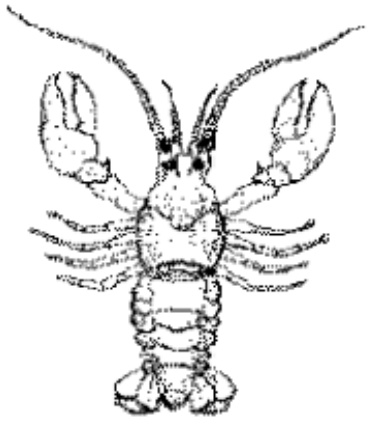
Assessment

1. Perform the previous method of sampling using the same organisms in this sample. Compare and contrast the previous method to the BWQS.
2. Explain the importance of Indicator Species.
3. How do the abiotic factors such as temperature and dissolved oxygen (DO) affect the abundance or presence of certain aquatic organisms?
4. How are aquatic organisms that are sensitive to pollution like the canary in a coal mine?
5. Besides temperature and dissolved oxygen, what other (a) chemical factors and (b) physical factors can affect the diversity of aquatic macroinvertebrates?
6. Why might the BWQS change from section to section of the same stream?

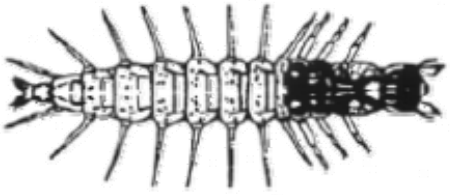
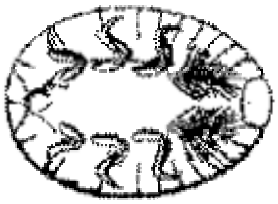
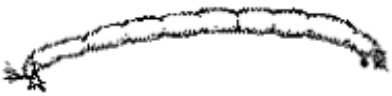
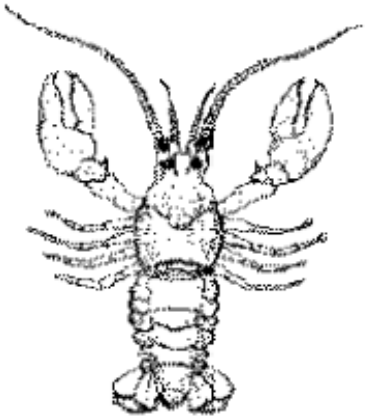
Handouts

- Data collection sheets from the Project Watershed website. www.projectwatershed.org
- Packet with spreadsheets and sample collections.

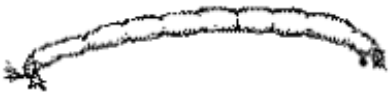
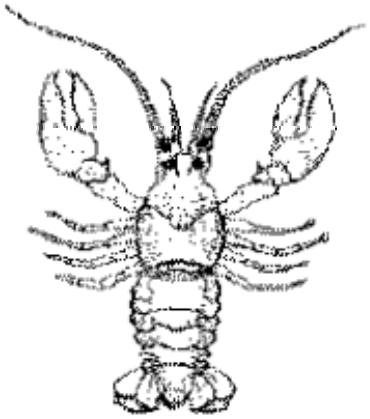
Investigating a Watershed Using BWQS:
Sample 1

(1) 10 collected 	(1) 10 collected 
(1) 4 collected 	(1) 2 collected 
(1) 6 collected 	(1) 2 collected 
(1) 4 collected 	(1) 2 collected 
	(1)

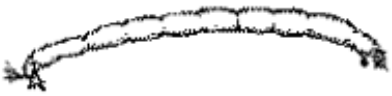
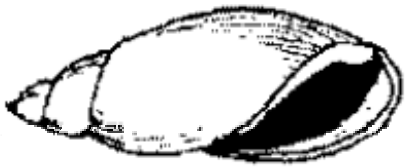
Sample 2

(2) 2 collected 	(2) 3 collected 
(2) 1 collected 	(2) 1 collected 
(2) 2 collected 	(2) 14 collected 
(2) 2 collected 	(2) 4 collected 

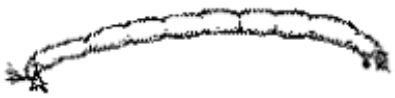
Sample 3

(3) 2 collected 	(3) 2 collected 
(3) 4 collected 	(3) 5 collected 
(3) 3 collected 	(3) 3 collected 

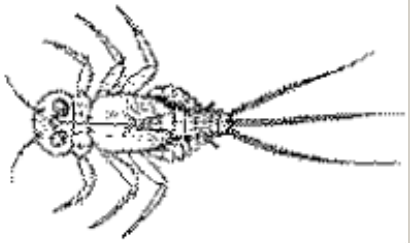
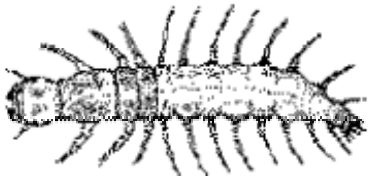
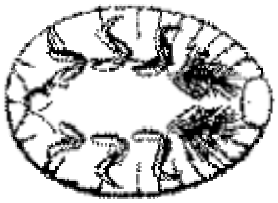
Sample 4

(4) 2 collected 	(4) 2 collected 
(4) 4 collected 	(4) 5 collected 
(4) 3 collected 	(4) 12 collected 

Sample 5

(5) 15 collected 	(5) 9 collected 
(5) 3 collected 	(5) 20 collected 

Sample 6

(6) 7 collected 	(6) 2 collected 
(6) 8 collected 	(6) 1 collected 
(6) 4 collected 	(6) 10 collected 
(6) 2 collected 	(6) 2 collected 

BIOLOGICAL WATER QUALITY MEASUREMENT

A biotic score is based on the tolerance of different benthic organisms to pollutants; some organisms are tolerant and some are sensitive. According to the biotic score method, sensitive organisms are assigned high values and tolerant organisms are assigned low values. The computer average value for a collected sample yields the Biotic Water Quality Score.

Procedure:

(1) Collect close to 100 organisms.
(2) Identify all the organisms using a macroinvertebrate identification key; record the number of each organism identified.
(3) Enter the number in the yellow number column. Excel will multiply the number of each organism identified by its BWQS and then divide the product by 10.
(4) Excel will calculate the individual organism scores to obtain the percentage of the total = BWQS.

Suggested ranges of Biotic Water Quality Scores for streams in New York State:

80-100	non-impacted (excellent water quality)
60-80	slightly impacted (good water quality)
40-60	moderately impacted (fair water quality)
0-40	Severely impacted (poor water quality)

BIOTIC WATER QUALITY SCORE WORKSHEET

AQUATIC ORGANISMS	NUMBER COLLECTED (A)	BIOTIC VALUE (B)	PRODUCT A X B	Product/10 A X B / 10
Aquatic worm	0	0	0	0
Beetle Larva (not riffle)	0	8	0	0
Black fly	0	6	0	0
Caddisfly	0	10	0	0
Clam	0	6	0	0
Cranefly	0	8	0	0
Crayfish	0	6	0	0
Damselfly	0	6	0	0
Dobsonfly	0	10	0	0
Dragonfly	0	6	0	0
Fishfly	0	6	0	0
Leech	0	2	0	0
Mayfly	0	10	0	0
Midge	0	5	0	0
Riffle Beetle	0	10	0	0
Scud	0	6	0	0
Snail	0	4	0	0
Sowbug	0	2	0	0
Stonefly	0	10	0	0
Water penny larva	0	10	0	0
			0	0
TOTAL	0		**BWQ SCORE =**	#DIV/0!

Source: Robert Bode, NYS DEC
Nov-99

NAME OF STREAM:
LOCATION:
DATE: