BRIDGEWATER COLLEGE
Bridgewater, Virginia

Honors Courses
Winter 1998-99

Name of Student: Heather E. Knupp

Name of Faculty Supervisor: Dr. Michael Hensley

Department: Biology **Number:** 500 **Title:** Honors Project

Title of Study: Analysis of the Stomach Contents of Native Trout

Description of the Work Completed: Native brook char or trout, Salvelinus fontinalis, were captured at three sites along upland mountain streams in western Rockingham County, Virginia. The same sites were sampled for benthic macroinvertebrates using standard field techniques. I assayed numbers of benthic macroinvertebrates in trout stomach contents, and then performed an analysis of variance to compare food use (by trout) to invertebrate availability (occurrence in field samples).

Evaluation Based Upon: weekly discussions of field and lab work, and a final paper.

Units of Credit: 3 **Grade:** A

Date: 2-5-99

Faculty Supervisor's Signature: Michael S. Hensley

LABORATORY ACTIVITY 7

A Survey of the Macroinvertebrate Population

OBJECTIVES

At the end of this laboratory activity, you should be able to:

- identify the major animal groups in the macroinvertebrate population of your stream site.
- calculate a diversity index and state its importance in evaluating water quality.
- make a statement concerning the quality of your stream site, based on the data collected.

INTRODUCTION

The diversity of life in an aquatic ecosystem varies considerably. Aquatic biologists classify organisms in aquatic environments mostly based on where they live: **neuston** are surface dwellers (water striders, duckweed), **plankton** are distributed through the water mass (microscopic plants and animals such as diatoms and protozoa), **nekton** are the free swimmers (fish, insects), and **benthos** live on or in the bottom substrate.

In this laboratory activity you will concentrate your efforts on studying the benthos. The benthos that you will study are classified as **macrobenthos;** specifically, the **macroinvertebrates** (*macro* = large, *invertebrate* = no backbone). These are defined by biologists as aquatic animals that can be seen with the unaided eye and that are retained by a sieve (U.S. Standard #30) with openings approximately 0.6 mm square. The major taxonomic groups making up the macroinvertebrates are insects and their larval (immature) forms, crustaceans (isopods, scuds), annelids (segmented worms), nematodes (roundworms), mollusks (clams, mussels, snails), and flatworms (planarians).

Flowing-water ecosystems place great demands on the organisms living there. The major physical parameter that influences their life is the rate of flow of the water. In particularly fast streams, organisms either are washed away or have adapted to life in the fast current. These adaptations assume several forms. For example, many organisms have very flattened bodies (mayflies), others are not only flat but have claws or hooks to hold on to the substrate (riffle beetles, sow bugs), and some even build nests and anchor them firmly to a rock or other substrate (caddis flies). Slower streams have more sediment, and it is possible to find organisms that burrow into the silt or mud, such as nematodes (roundworms), annelids (segmented worms), and certain species of mayfly and dragonfly larvae. Others, such as freshwater shrimp and daphnia, are able to swim in the more slowly moving water and are not dependent upon special adaptations to keep from being washed away.

The macroinvertebrates are very sensitive to stress in the environment and are useful for determining the health of a stream. The diversity of species in the macroinvertebrate population provides a wide range of response to environmental stress, and a change in water quality will readily cause a shift in population density of one or more species. Stream benthos can be classified into three categories according to their tolerance to pollution.

1. Pollution-sensitive (mayflies, stone flies, caddis flies, crayfish)
2. Moderately pollution-tolerant (net-spinning caddis flies, water penny beetles, scuds, hellgrammites, dragonfly nymphs, fingernail clams)

3. Pollution-tolerant (fly larvae, snails, flatworms, leeches, beetles, sow bugs)

Although representatives of all three groups may be present in a stream, environmental stress can be detected by observing an increase in the population of organisms in groups 2 and 3 and a decline in the organisms in group 1.

The idea of biological diversity was introduced in Laboratory Activity 6. In this activity you will extend this concept to include a mathematical calculation of a diversity index and use it as a more formal measure of the stress (if any) your stream is undergoing. The basic premise of a diversity index is that undisturbed biological communities have a large number of species with no individual species predominating. Conversely, in a stressed environment, the number of different species is reduced, and there is a tendency for only a few species to assume a dominant role in the community structure (see Table 7.1).

To calculate a diversity index for your stream site, you will need to place the macroinvertebrates that you collect into look-alike groups as you did in Laboratory Activity 6. Look-alike groups will save you from having to use complicated taxonomic keys to classify organisms. Even though it may sound "unscientific," this classification scheme will save you considerable time and is a reasonably accurate way to classify organisms to the taxonomic level of class, family, genera, and, in some cases, even species.

MATERIALS

Paint brush (2 in. wide)
Spatula
Wide-mouthed jars of isopropyl alcohol (70%) with glycerin
D-ring net or hand screen
Stick or trowel
White enamel pan
Forceps
Suber net
Watch with second hand
Magnifying glass
Dissecting microscope
Calculator with natural log function

PROCEDURE

At the Stream Site

There are several ways to collect benthic organisms, two of which are described below. Figure 7.1 illustrates three different nets you may use to collect these organisms. Your instructor will select the method and device most suitable for you and your partner.

Method 1

1. Work through your site, scraping off the organisms from the bottom of the larger rocks with

Figure 7.1 Collecting nets

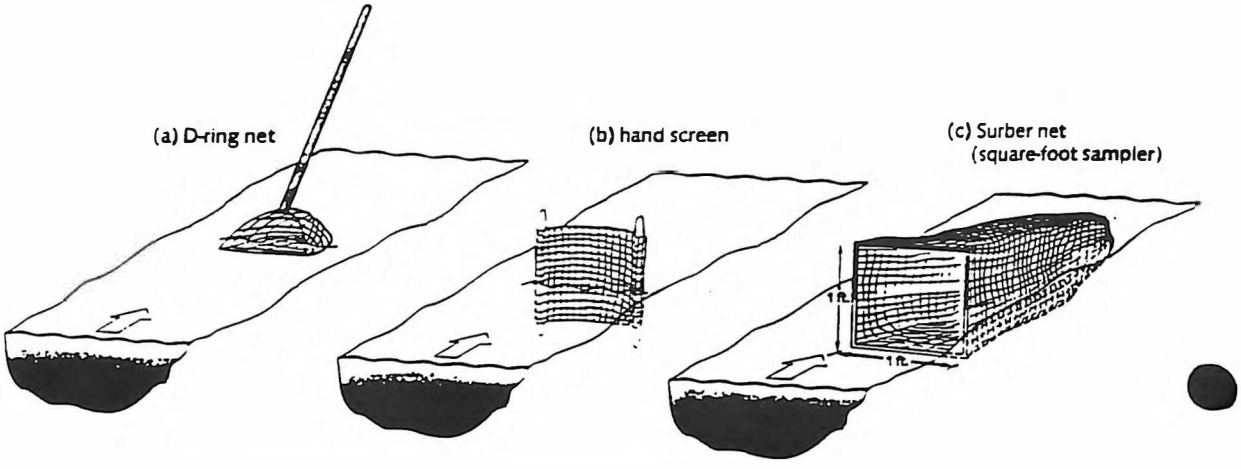


Table 7.1 Comparison of macroinvertebrate organisms by station in a western Maryland stream*

	Station 1	Station 2	Station 3	Station 4
Class: Tubellaria (flatworms)				
Dugesia sp.	1	2	—	—
Class: Oligochaeta (segmented worms)	1	—	6	1
Class: Hirudinea (leeches)	3	—	4	1
Class: Gastropoda (snails)				
Physa sp.	—	—	—	1
Campaloma sp.	4	3	—	—
Order: Isopoda (sow bugs)				
Asellus sp.	7	2	36	37
Order: Amphipoda (scuds)				
Gammarus sp.	2	—	4	4
Order: Ephemeroptera (mayflies)				
Tricorythodes sp.	4	1	—	—
Baetis sp.	—	—	—	2
Ephemerella sp.	7	6	—	3
Stenonema sp.	1	1	—	6
Stenacron sp.	—	—	—	17
Order: Trichoptera (caddis flies)				
Hydropsyche sp.	14	10	3	11
Cheumatopsyche sp.	46	48	9	9
Orthotrichia sp.	—	3	—	—
Order: Plecoptera (stone flies)				
Acroneuria sp.	—	—	—	1
Order: Megaloptera (helligrammite)				
Chauliodes sp.	—	—	—	2
Order: Diptera (true flies)				
Family: Chironomidae	17	—	58	1
Chironomus sp.	—	—	3	—
Simulium sp.	1	—	3	—
Antocha sp.	1	—	—	—
Order: Coleoptera (beetles)				
Stenelmis sp.	9	12	—	2
TOTAL ORGANISMS	118	88	126	98

*This table summarizes the data from a stream in western Maryland studied by the authors. Numbers indicate individuals in 3 ft.^{2} (0.28/m^2). Measurements were taken at 4 stations: at that time, one of these stations (3) was subject to considerable stress from waste water effluent. Note that two groups of organisms, *Asellus* (pollution-tolerant crustaceans) and *Chironomidea* (true flies) have rather large populations, while the sensitive species (mayflies, caddis flies, stone flies) are absent or considerably reduced in number.

Figure 7.2 Collecting macroinvertebrates with a D-ring net

a brush or thin spatula. Sample the area within your site for 20–30 minutes. Place the organisms in a wide-mouthed jar of 70% isopropyl alcohol for transport to the laboratory.

2. Return the rocks you disturbed in the stream to their original positions.
3. After removing the organisms from the larger rocks, select several areas (at least three) and use a D-ring net (see Figure 7.1a) to collect organisms from the stream bottom (see Figure 7.2). Hold the net with the open end facing upstream and have your partner stir the bottom of the stream bed with a stick or trowel for about 1 minute.[1]
4. Empty the contents of the net into an enamel pan (Figure 7.3) and remove the organisms with a pair of forceps or spatula. Place all organisms in your collecting jar and return the residue to the stream bed.
5. Repeat the process at two more sites.

1. In place of a D-ring net, you may use a hand screen made of two wood or metal rods attached to a piece of nylon net. The screen should be about 2 ft. long and 1 ft. wide (see Figure 7.1b).

Method II

This method uses a net called the Suber square foot sampler (Figure 7.1c). The Suber net will allow you to sample the stream bottom quantitatively. Presumably you will collect all the organisms in one square foot of stream bed and you can then express your results as number of organisms per square foot.

1. Hold the net with the open end upstream. The water must be shallow so that it doesn't cover the net.
2. Have your partner lift large rocks within the framed square foot area and brush or scrape off the organisms into the net. Be sure to hold the rocks directly in front of the net opening to avoid losing organisms. Place the rocks outside the frame when you are finished.

Figure 7.3 Sorting organisms in an enamel pan

3. With a stick or trowel, stir the stream bottom within the area of the frame to a uniform depth for several minutes. Keep track of the length of time you sample your site and keep this time constant when sampling the other sites.
4. Shake the contents of the net out onto a white enamel pan and then pick out the organisms from the gravel and sediment.
5. Place the organisms into a wide-mouthed jar of 70% isopropyl alcohol for transport to the laboratory. Return the displaced rocks, sediment, and gravel to the stream.
6. Repeat these steps at two other sites, remembering to spend the same amount of time at each location.

In the Laboratory

1. Spread all of the organisms you have collected onto a white enamel pan and study them carefully. If you are comparing several sites, be sure to do only one site at a time.
2. Study each organism, noting its size, shape, and color. If necessary, use a magnifying glass or dissecting microscope to examine each specimen.
3. After studying each specimen, move it to a section of your tray away from the others. Keep doing this until you have sorted all specimens into look-alike groups (see Figure 7.4).
4. In Question 1 in the Evaluation, make a sketch of a representative organism from each group. Just outline the major features of the body; don't get bogged down in detail. Label the groups A, B, C, and so on.
5. Use the diagrams and information in Table 7.2, "Description of Major Benthic Phyla and Classes," to help you place each organism into a taxonomic group.

Figure 7.4 Look-alike groups sorted into petri dishes

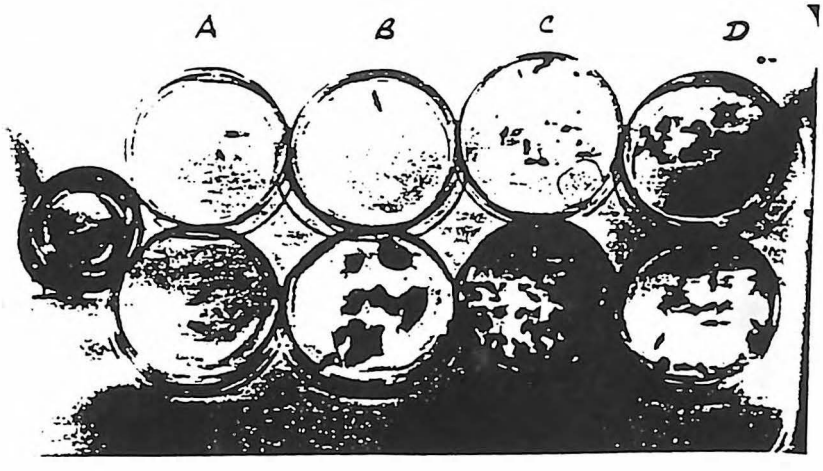
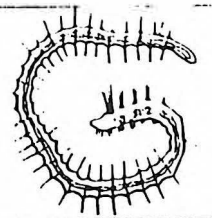
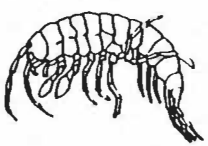
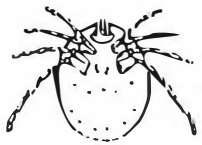


Table 7.2 Description of major benthic phyla and classes

Phylum	Class	Body shape	Color	Locomotion	Habitat	Diagram
Platyhelminthes (flatworms)	Turbellaria (free-living flatworms)	Flat, elongated, unsegmented, 5–10 mm long	Brown, gray-black	Gliding	Under submerged plants and rocks	
Nematoda (roundworms)		Cylindrical, elongated, unsegmented, less than 1 cm long	Colorless to blackish, often translucent	Constant, rapid, whiplike	In organic material and debris	
Annelida (segmented worms)	Oligochaeta (aquatic earthworms, *Tubifex*)	Cylindrical ringlike segments, about 1–30 mm long	Varies, often red	Crawling	In organic material and debris	
	Hirudinea (leeches)	32 segments, 3–5 grooves per segment, suction disks at anterior and posterior ends	Brown	Crawling	Attached to submerged objects, logs, and plants	
Arthropoda (jointed appendages; hard, chitinous exoskeleton, segmented body)	Crustacea (crayfish, shrimp, sow bugs)	2 pairs of antennae, usually numerous paired appendages, considerable variation in size—from microscopic to 10 cm	Varied	Swimming, crawling	Attached to submerged objects, logs, and rocks	

Phylum	Class	Body shape	Color	Locomotion	Habitat	Diagram
Arthropoda (continued)	Insecta (immature forms)	Segmented body (head, thorax, abdomen), thorax with 3 pairs of jointed legs, 1 pair of antennae on head (see key to aquatic insect larvae)	Brown, black, green	Crawling	Attached to submerged objects, logs, rocks, and plants	
	Arachnida (water mites)	Globular to oval in shape, 8 legs, 0.4–3.0 mm long	Brightly colored	Crawling	Attached to submerged objects, logs, rocks, and plants	
Mollusca (soft body in 1 shell or 2 calcareous [calcium carbonate] shells)	Gastropoda (snails)	Body enclosed in 1 coiled spiral shell, may be cone-shaped, 2–70 mm long	Gray or black shell	"Walking" with foot	Attached to submerged objects, logs, rocks, and plants, or buried in mud	
	Pelecypoda (clams, mussels)	Body enclosed in 2 shells joined by elastic hinge, 2–25 mm long				

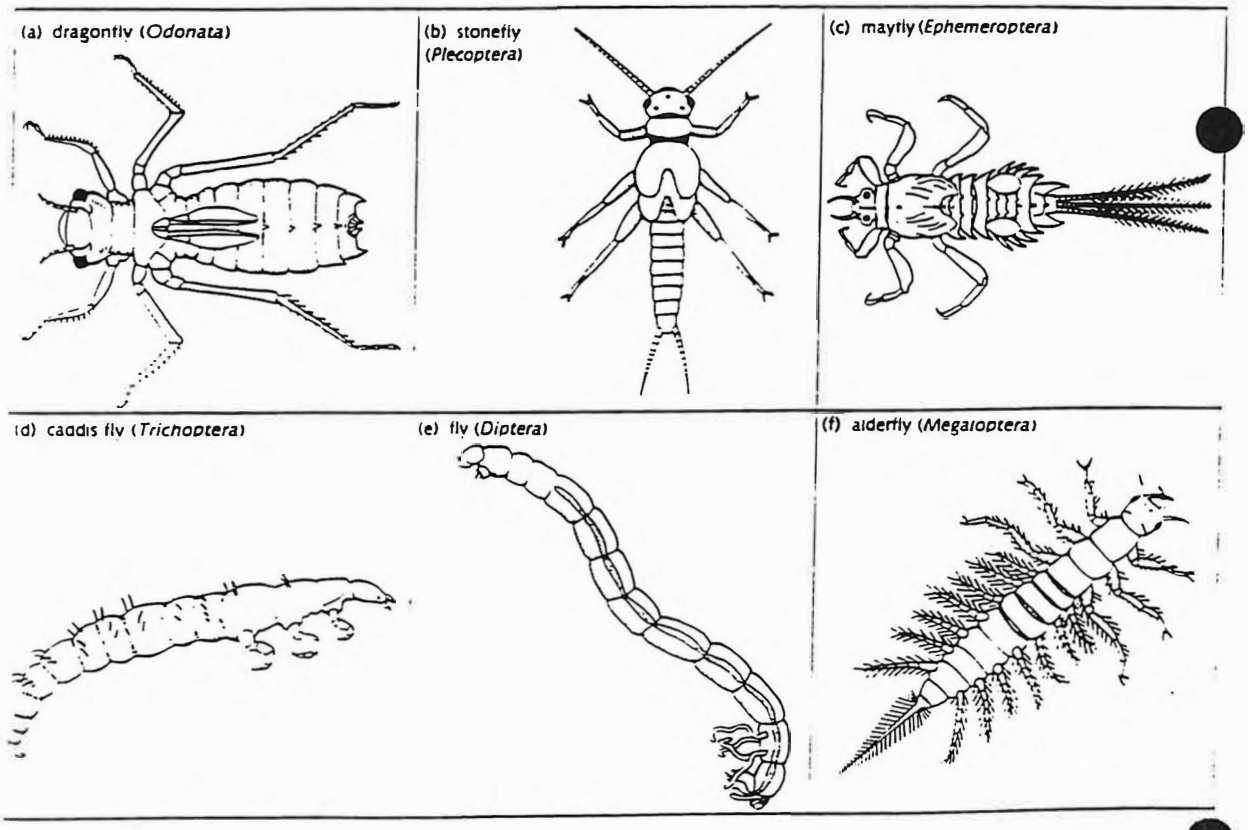
6. Identify insect larvae to the order level of classification according to the Dichotomous Key to Aquatic Insect Larvae and the diagrams in Figure 7.5. (You may wish to use more detailed keys, if available, and attempt to assign your specimens to a genera or even a species.)

7. List the groups of organisms by name or letter in Question 2 in the Evaluation. Using the information in the introduction, attempt to indicate whether or not they are tolerant, moderately tolerant, or intolerant to pollution.

Dichotomous Key to Aquatic Insect Larvae[2]

1. (a) larvae with externally developing wings: 2
   (b) larvae with internally developing wings: 5
2. (a) mouth parts adapted for biting: 3
   (b) mouth parts joined in the form of a sucking beak, directed backward beneath the head: *Hemiptera* (water bugs)
3. (a) long, slender tails; labium (lower lip) not longer than head and not hinged on itself: 4
   (b) three tails, either leaflike or as small spinous appendages; extended labium much longer than head and, when at rest, folded on itself like a hinge between forelegs: *Odonata* (dragonflies, damselflies)

Figure 7.5 Representative aquatic insect larvae



2. Adapted from Needham, James G. and Needham, Paul R., *A Guide to the Study of Freshwater Biology*, 5th ed. (Oakland: Holden-Day, Inc.) 1962, p. 30. Reproduced with permission of McGraw-Hill, Inc.

4. (a) gills found under plates of thorax (where legs are attached); two tarsal (terminal segment of leg) claws; two tails: *Plecoptera* (stone flies)

   (b) gills usually positioned on sides of abdomen; single tarsal claw; usually three tails: *Ephemeroptera* (mayflies)

5. (a) jointed thoracic legs present: 6

   (b) jointed thoracic legs absent; legless or with abdominal prolegs (short, fleshy limbs): *Diptera* (true flies)

6. (a) long lateral filaments located on abdominal segments: *Megaloptera* (dobsonflies)

   (b) lateral filaments missing; often showing minute gill filaments; cylindrical body generally found in cases attached to rocks: *Trichoptera* (caddis flies)

Calculating the Diversity Index

A formula known as the Shannon-Weaver diversity index allows you to calculate the diversity of your stream site. This measure of diversity produces values from 0 to 4. A diversity index between 0 and 1 indicates water of poor quality; values between 1 and 3 are indicative of intermediate quality water; and values above 3 are typical of good water quality. The Shannon-Weaver index assumes that all organisms have been identified to species. Because you are not an experienced taxonomist, your identifications will probably not be this exact. If you examined the organisms closely when you arranged them into look-alike groups, however, the margin of error will not be significant.

The formula for the Shannon-Weaver index is

$$N = (P_i)(-\ln P_i)$$

where N = Shannon-Weaver index

$$P_i = \frac{\text{number of organisms in a given species}}{\text{total number of all organisms}}$$

and $-\ln P_i$ = natural log of P_i.

When calculating the index with your own data, follow the steps suggested below, filling in the chart in the Evaluation as you go along. You will need a calculator to determine the natural logs. Study the following sample calculation before attempting your own.

Sample Calculation

A population of organisms collected from a stream bed has the following composition:

Organism A = 25
B = 17
C = 37
D = 5
Total = 84

Organism	Frequency (P_i)	Natural log ($-\ln P_i$)	(P_i)($-\ln P_i$)
A	$\frac{25}{84} = 0.298$	1.211	0.361
B	$\frac{17}{84} = 0.202$	1.598	0.323
C	$\frac{37}{84} = 0.440$	0.820	0.362
D	$\frac{5}{84} = 0.060$	2.821	0.169
			$N = 1.22$

The Shannon-Weaver index is the sum of the products in the last column. Thus, $N = 1.23$, indicating a stream of intermediate water quality.

Once you feel comfortable with how the formula works, calculate your own diversity index using the data that you have collected from your stream site.

1. Calculate the P_i and $-\ln P_i$ values for each group of organisms in your collection. Record your data in the columns marked "Frequency" and "Natural log" in Question 4 in the Evaluation.
2. Calculate the product (P_i)($-\ln P_i$) for each group. Record your data in the last column in Question 4.
3. Add the values in this last column to determine the diversity index (N).

NAME _____ SECTION _____ DATE _____

2. List all of the groups or organisms you collected by letter, general characteristics, and—if possible—name and pollution sensitivity.

Group	Name (optional)	General characteristics	Pollution sensitivity (optional)*

*Tolerant, moderately tolerant, sensitive

3. If you have used a Suber net to collect your organisms, calculate the number of each group per square foot according to the following formula.

$$\frac{\text{Total organisms in group}}{\text{Total number of square feet sampled}} = \text{Organisms/ft.}^2$$

Sample calculation:

$$\frac{327}{10} = 32.7 \text{ organisms/ft.}^2$$

Enter your data in the following table.

Organism	#/ft.^{2}	Organism	#/ft.^{2}

4. Enter your data in the following table and calculate the Shannon-Weaver diversity index for your study area.

Organism	Frequency (P_i)	Natural log (ln P_i)	(P_i)(−ln P_i)

5. Based on the data you have collected, write a statement that indicates the quality of your stream water.

Macroinvertebrates as Indicators of Stream Health

Brook S. McDonald Gary W. Mullins Stuart Lewis

As part of preserving and managing the river resources of Ohio, that state's Department of Natural Resources has initiated a citizen's stream monitoring program. The stream quality monitoring program (Kopec & Lewis 1986) is being used to establish a baseline data bank on streams designated and managed as components of Ohio's Scenic Rivers Program. Benthic macroinvertebrates found in the stream, such as the stonefly, mayfly and water penny beetle larva, are used as key indicators of water quality and stream health.

Since the program's inception in 1982, much of the monitoring has been carried out by students. Teachers have capitalized on the opportunity by getting students involved in a citizen action program while providing them with a field exercise in stream ecology. McDonald (1987) reported that high school biology students do learn a significant amount of benthic macroinvertebrate ecology as a result of participating in the Ohio Scenic Rivers Stream Quality Monitoring Program (SQM).

Because of the educational value of SQM in schools, Illinois has recently implemented an SQM program. Several other states, including Kentucky, North Carolina and Massachusetts, also have citizen stream monitoring programs.

SQM can usually be performed on any suitable stream; therefore, it can be used as a field biology exercise. The objectives are:

1. Introduce students to the relationships between benthic macroinvertebrates and their physical environment.
2. Introduce students to a biological method for determining stream health.
3. Introduce students to sampling procedures using qualitative methods.
4. Provide students the opportunity to directly contribute to the preservation and management of local waterways.

Brook S. McDonald, a Master of Science graduate from Ohio State University's School of Natural Resources, is manager of interpretive services, Wheaton Park District, 666 S. Main St., Wheaton, IL 60187. **Gary W. Mullins**, Ph.D., is an associate professor in the School of Natural Resources, Ohio State University, Columbus, OH 43210. **Stuart Lewis** is administrator for the Ohio Scenic Rivers Program, Ohio Department of Natural Resources, Division of Natural Areas and Preserves, 1889 Fountain Square, Columbus, OH 43224.

Ecology

SQM uses benthic macroinvertebrates found in the riffles of streams and rivers. Although macroinvertebrates are found in other habitats within stream ecosystems, they are most highly concentrated in riffles. Increased dissolved oxygen and available substrates are characteristic of riffles. Suitable streams must have a continuous flow of water over riffles throughout the year and possess riffle areas large and diverse enough to support a benthic macroinvertebrate population.

Macroinvertebrates are defined for the students as aquatic organisms that can be seen with the naked eye and lack a backbone. In freshwater streams the dominant species are aquatic insects in their immature forms. Mollusks, arthropods and annelids, also considered macroinvertebrates, are found in the streams.

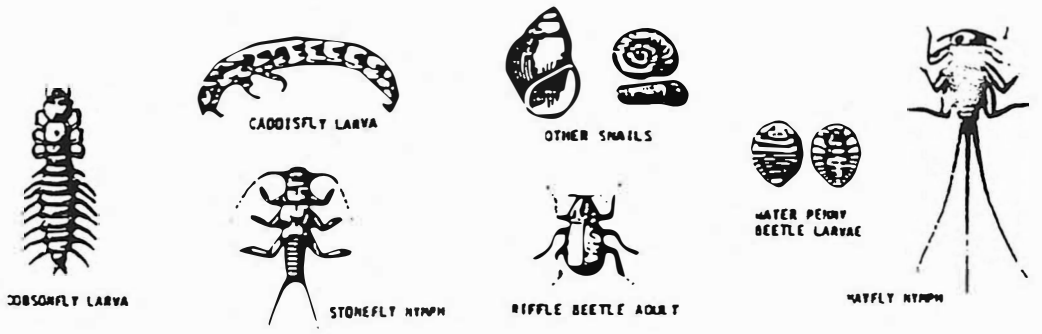
Macroinvertebrates are divided into three groups according to their tolerance to pollution (See Figure 1). Organisms in Group 1 are considered pollution-intolerant and their dominance usually signifies good water quality. Included in this group are the mayfly and stonefly nymphs, dobson fly, caddis fly, water penny beetle larva, adult riffle beetle and the gill-breathing snails. Group 2 organisms can exist in a wide range of water quality conditions and include freshwater clams and mussels, crayfish, dragonfly and damselfly nymphs, crane larva, sowbugs and scuds. Group 3 organisms are considered tolerant of water degradation and include leeches, midge and black fly larva, aquatic worms and the lung-breathing (pouch) snails. They can tolerate some types of pollution and their numbers often increase under these conditions as Group 1 and 2 organisms decline in number. Dominance by Group 3 usually signifies poor water quality. By collecting samples of benthic macroinvertebrate communities and calculating their numbers, the students will be able to estimate the relative health of a stream.

Organisms that are pollution-tolerant do not necessarily prefer to live in polluted water but can tolerate such an environment if the water quality

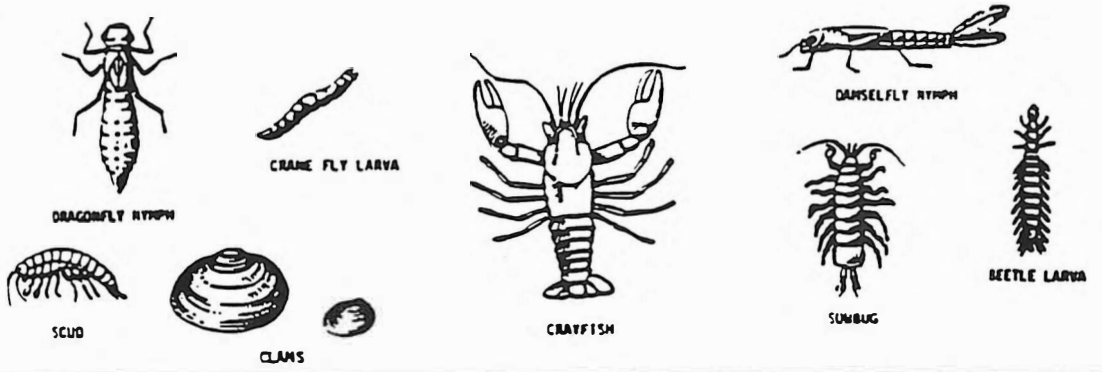
Figur

MACROINVERTEBRATE TAXA GROUPS

GROUP 1 (*These organisms are generally pollution-intolerant. Their dominance generally signifies GOOD WATER QUALITY*)



GROUP 2 (*These organisms can exist in a wide range of water quality conditions.*)



GROUP 3 (*These organisms are generally tolerant of pollution. Their dominance usually signifies POOR WATER QUALITY.*)

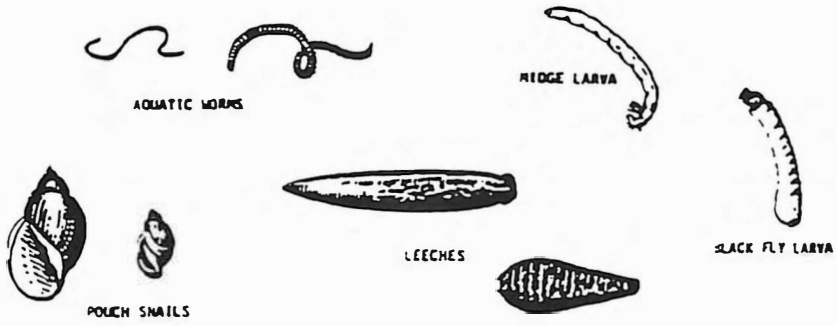


Figure 1. Macroinvertebrate taxa groups. Source: Ohio Department of Natural Resources.

changes. Some of these organisms are found living in such degraded situations because of low competition with other macroinvertebrates.

Macroinvertebrates, especially the immature aquatic insects, are one of the best indicators for assessing overall stream health. Macroinvertebrates tend to stay in the same general area and become adapted to their particular habitats. Thus, their survival is limited by the availability of food, water temperature, stream current, presence or absence of predators, and depth and type of substrate. Their populations change rapidly enough in response to changes in these limiting factors to provide an early warning signal of stream environment degradation (Odum 1971). Since most organisms have multiple-year life cycles and are restricted to their immediate environment, they cannot readily escape changes in stream quality. Therefore, if stream quality decreases, a considerable period of time may be required for the natural macroinvertebrate population to fully recover. Based on the diversity and relative pollution tolerance of the organisms collected, a stream assessment can be calculated.

Equipment

SQM equipment is inexpensive and can be readily obtained. It includes:

1. One piece of 4-by-4 foot fiberglass or nylon netting with 1/16 inch or smaller mesh stretched between two poles and weighted at the front of the net. (Some states require a scientific collecting permit for the use of small mesh collecting nets.)
2. White or light colored enamel or plastic pans approximately 8 by 12 inches and four inches deep.
3. Magnifying glasses or "bug boxes."
4. Laminated (waterproof) identification sheets that show organisms divided into respective groups or identification keys.
5. Data forms and pencils.
6. Waders where water temperature is too uncomfortable or unacceptable for prolonged wading.

Procedures

The most important part of the exercise is to find an appropriate stream site. Select riffles that have a bottom composition of mostly small- to medium-sized rocks, cobbles and gravel. All sand or silt or smooth solid bedrock bottoms will not provide the proper habitat and thus will be nearly devoid of macroinvertebrates. Students should approach the area from the downstream side so as not to disturb the sample area. As one or two students hold the net, slightly angled with the current, the other students walk in front of the net and begin the collection procedure. All rocks the size of a fist or larger are rubbed thoroughly under the water, in front of the net, to dislodge all organisms into the seine. The current then carries the organisms into the net. After thoroughly scrubbing these rocks, the next step is to disturb the sampling area in front of the net using the feet to kick up the stream bottom. This allows for the collection of the remaining organisms that burrow into the substrate. The final seining step is to carefully scoop up the net, taking care not to allow water to rush over the top, and to carry the seine to a clean, flat, dry area for examination.

Place examination containers filled with one or two inches of clear streamwater next to the net. The organisms are immediately picked out of the net and placed into the water-filled containers. Repeat this collection procedure to insure an adequate sample. Care should be taken to not injure the organisms. After all the different organisms are removed from the net, thorough cleansing and air drying of the net are required before storing. When the collecting is finished, the next step is to identify all the organisms. This is the most time-consuming aspect of the procedure; pre-trip activities that encourage students to become familiar with stream ecology and the 20 or so types of macroinvertebrates will save time. Keys or identification sheets aid in identification and categorizing according to the macroinvertebrate tolerance to pollution. Most books about freshwater animals describe benthic macroinvertebrates thoroughly (see references).

To draw a conclusion about the relative stream health, a determination of the dominant group must be made. If Group 1 and 2 organisms (as shown in Figure 1) dominate the sample, water quality is good. If Group 3 organisms dominate the sample, the water quality is somewhat degraded.

Another method, as employed by the Ohio Scenic Rivers' SQM program, is to assign index values to different taxa in each group and add up cumulative index values. For example, Group 1 taxa receive an index value of 3, Group 2 taxa an index value of 2 and Group 3 taxa an index value of 1. The higher the cumulative index value, the better the stream environment. A range for water quality is shown in Figure 2.

If students calculate the stream quality to be poor, they can search for a source of pollution such as an incoming tributary, sewage treatment plant outfall or industrial or household discharge. This is accomplished by moving upstream approximately one mile and repeating the sampling techniques and calculations. If the index value is the same or lower, move further up stream.

At the sampling point where the stream quality begins to improve, as shown by a higher index value,

Stream Quality Assessment
Observations and Analysis

The organisms in Figure 1 are grouped into three categories:

GROUP 1 (pollution-intolerant or good quality indicators)
GROUP 2 (organisms that can exist in both extremes of quality)
GROUP 3 (pollution-tolerant or poor quality indicators)

The organisms in these three groups are assigned a group index value.

GROUP 1 = 3 GROUP 2 = 2 GROUP 3 = 1

The analysis procedure consists of counting the number of types of organisms in each category and multiplying the group index value.

EXAMPLES:	GROUP 1 TAXA		GROUP 2 TAXA		GROUP 3 TAXA	
	CADDISFLY (S) STONEFLY (S) MAYFLY (S)	3x3 = 9	DRAGONFLY (S) CRAYFISH CLAM (S)	3x2 = 6	BLACKFLY (S) MIDGE (S)	2x1 = 2

The respective group index values are then added together to find the cumulative index value (which in the above case would be 17). By referring to the following chart, the stream quality assessment can thus be determined.

STREAM QUALITY ASSESSMENT	CUMULATIVE INDEX VALUE
EXCELLENT	23 and above
GOOD	17 - 22
FAIR	11 - 16
POOR	10 or less (SEE ACTION PROCEDURE ON PAGE 8)

NOTE: The organisms on the stream quality assessment form used in the field are to be recorded by placing a letter code in the corresponding block. Each letter represents your estimated count.

Figure 2. Stream quality assessment observations and analysis. Source: Ohio Department of Natural Resources.

the students are to begin sampling back downstream for the source and a decreased water quality index value. Careful recording of field data is crucial for entry into a classroom computer and for replication of monitoring by classes in future years.

Ohio uses the assessment forms computed by students and other field monitors to determine impact. If an impact is occurring, the Ohio Environmental Protection Agency is notified and it follows up with more intensive stream investigations to find the source.

In addition to taxonomy, students should be encouraged to measure water temperature, pH, dissolved oxygen and turbidity and to collect water samples for laboratory analysis. If thermometers and pH meters are not readily available, most biological supply houses offer fairly reliable versions at reasonable prices. Measures of pH provide an avenue for follow-up activities addressing acidic deposition from air and land sources as well as students' exploring the role of pH in determining water quality and the presence of certain aquatic organisms.

Dissolved oxygen provides further bases for students to begin exploring the interactions of additional factors influencing water quality and the stream ecosystems. Explanation of the level and cause of turbidity may provide students with further clues to the status of the stream. Where there are suspended materials such as industrial or household wastes, suspended soil or algae, encourage students to explore laboratory procedures that will separate the solids for further studies. Binocular scopes and microscopes can be used to explore the biota of the freshwater samples.

All these techniques, beyond the field experience, have the potential to help students discover the complexities of stream ecology and of maintaining stream quality. By systematically recording these data on the classroom computer, students have the opportunity to create simulations and models that mathematically and graphically represent the workings of the stream. The computerized data banks also provide future students with baseline data with which to compare their class' findings.

Where possible, involve the school's chemistry program, local water quality laboratories, state or local environmental protection agencies or local industries with water quality laboratories. Detailed water chemistry profiles provide students one more parameter for their stream quality model.

The utility of the SQM program is that it can be adapted to a variety of curricular and temporal needs. A short-term exercise requiring a pretrip activity, one visit to a nearby stream to sample organisms and a follow-up activity have been shown to be effective teaching tools (McDonald 1987). If appropriate to the curriculum, the field activity can include collecting a variety of data beyond macroinvertebrates and the data can be used throughout the year for computer modeling and to illustrate the complex interactions within an aquatic environment.

The Ohio Department of Natural Resources uses student data to monitor changes in water quality. Visits to the classroom by natural resource managers or the use of special library assignments can encourage students to become involved in the socio-political aspects of insuring that water quality laws are being enforced.

Water is a universal attraction to all humans and has been so throughout the ages. Whether for transportation, recreation, nourishment or to dilute and carry away our waste, the link is ever present. Stream Quality Monitoring Programs such as those found in Ohio and Illinois provide students and teachers an opportunity to explore an aquatic community and contribute to the monitoring and protection of that system.

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KEY TO ORDERS OF AQUATIC INSECTS; NYMPHS, LARVAE, PUPAE, AND ADULTS

1. Usually inactive; pupae.....2
   Active; nymphs, larvae, and adults.....4
2. Maggot-like, but the body shorter, hard, and dark-colored.
   Pupae of **DIPTERA** (flies), p. 628
   Mummy-like, with the future adult appendages more or less concealed in translucent cases and held close to the body in a fixed position.....3
3. Within a case composed of bits of vegetation or mineral matter.
   Pupae of **TRICHOPTERA** (caddis flies), p. 565
   Without a case, but sometimes in a silken tube or fibrous cocoon.
   Pupae of **DIPTERA** (flies), p. 628
4. Without jointed thoracic legs; maggot-like....Larvae of **DIPTERA** (flies), p. 628
   Jointed thoracic legs present.....5
5. With long, segmented, filamentous appendages at the posterior end.....6
   Posterior filamentous appendages absent, or, if present, then not long and segmented.....7
6. With two posterior filamentous appendages; two tarsal claws; usually with finger-like tracheal gills on ventral side of thorax.
   Nymphs of **PLECOPTERA** (stoneflies), p. 500
   Usually with three, sometimes two, filamentous posterior appendages; one tarsal claw; with tracheal gills on lateral margins of abdominal segments.
   Nymphs of **EPHEMEROPTERA** (mayflies), p. 509

7. With large hard or leathery forewings covering the abdomen; biting mouth parts.
   Adult **COLEOPTERA** (beetles), p. 588
   Wings, if present, of another structure.....8
8. Small insects, usually less than 3 mm. long; wingless; with a long forked appendage beneath the abdomen used in springing; on the surface of quiet waters.
   Immature and adult **COLLEMBOLA** (springtails), p. 497
   Usually more than 3 mm. long; wings present or absent; no abdominal appendage for springing; usually submerged.....9
9. With wing rudiments (pads) or functional wings; nymphs and adults.....10
   Without wing rudiments or functional wings; larvae.....11
10. Sucking mouth parts in the form of a long jointed beak.
    Nymphs and adults of **HEMIPTERA** (bugs), p. 541
    Chewing mouth parts; labium, when extended, long and scooplike, and when folded serving as a mask covering the other mouth parts; with or without platelike caudal gills.....Nymphs of **ODONATA** (dragonflies and damselflies), p. 522
11. With slender, decurved, piercing and sucking mouth parts about half as long as the body; small larvae living in or on sponges.
    NEUROPTERA (spongilla fly larvae), p. 563
    With biting mouth parts.....12
12. With five pairs of abdominal prolegs.
    LEPIDOPTERA (aquatic caterpillars), p. 585
    Prolegs absent, or confined to the last abdominal segment.....13
13. Each abdominal segment with one pair of stout lateral processes.
    MEGALOPTERA (hellgrammites, alderfly and fishfly larvae), p. 560
    No stout lateral abdominal processes, but sometimes with long, thin, lateral filamentous processes; a few beetle larvae with four stout hornlike processes on each body segment.....14
14. With a pair of terminal abdominal prolegs; usually with small, finger-like, abdominal tracheal gills; usually in fixed or portable cases.
    TRICHOPTERA (caddis fly larvae), p. 565
    Without terminal prolegs; rarely with long, thin, filamentous, abdominal tracheal gills; without cases.....**COLEOPTERA** (beetle larvae), p. 588

KEY TO ORDERS OF AQUATIC INSECTS; NYMPHS, LARVAE, PUPAE, AND ADULTS

1. Usually inactive; pupae.....2
   Active; nymphs, larvae, and adults.....4
2. Maggot-like, but the body shorter, hard, and dark-colored.
   Pupae of **DIPTERA** (flies), p. 628
   Mummy-like, with the future adult appendages more or less concealed in translucent cases and held close to the body in a fixed position.....3
3. Within a case composed of bits of vegetation or mineral matter.
   Pupae of **TRICHOPTERA** (caddis flies), p. 565
   Without a case, but sometimes in a silken tube or fibrous cocoon.
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5. With long, segmented, filamentous appendages at the posterior end.....6
   Posterior filamentous appendages absent, or, if present, then not long and segmented.....7
6. With two posterior filamentous appendages; two tarsal claws; usually with finger-like tracheal gills on ventral side of thorax.
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   Usually with three, sometimes two, filamentous posterior appendages; one tarsal claw; with tracheal gills on lateral margins of abdominal segments.
   Nymphs of **EPHEMEROPTERA** (mayflies), p. 509

7. With large hard or leathery forewings covering the abdomen; biting mouth parts.
   Adult **COLEOPTERA** (beetles), p. 588
   Wings, if present, of another structure.....8
8. Small insects, usually less than 3 mm. long; wingless; with a long forked appendage beneath the abdomen used in springing; on the surface of quiet waters.
   Immature and adult **COLLEMBOLA** (springtails), p. 497
   Usually more than 3 mm. long; wings present or absent; no abdominal appendage for springing; usually submerged.....9
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   Without wing rudiments or functional wings; larvae.....11
10. Sucking mouth parts in the form of a long jointed beak.
    Nymphs and adults of **HEMIPTERA** (bugs), p. 541
    Chewing mouth parts; labium, when extended, long and scooplike, and when folded serving as a mask covering the other mouth parts; with or without platelike caudal gills.....Nymphs of **ODONATA** (dragonflies and damselflies), p. 522
11. With slender, decurved, piercing and sucking mouth parts about half as long as the body; small larvae living in or on sponges.
    NEUROPTERA (spongilla fly larvae), p. 563
    With biting mouth parts.....12
12. With five pairs of abdominal prolegs.
    LEPIDOPTERA (aquatic caterpillars), p. 585
    Prolegs absent, or confined to the last abdominal segment.....13
13. Each abdominal segment with one pair of stout lateral processes.
    MEGALOPTERA (hellgrammites, alderfly and fishfly larvae), p. 560
    No stout lateral abdominal processes, but sometimes with long, thin, lateral filamentous processes; a few beetle larvae with four stout hornlike processes on each body segment.....14
14. With a pair of terminal abdominal prolegs; usually with small, finger-like, abdominal tracheal gills; usually in fixed or portable cases.
    TRICHOPTERA (caddis fly larvae), p. 565
    Without terminal prolegs; rarely with long, thin, filamentous, abdominal tracheal gills; without cases.....**COLEOPTERA** (beetle larvae), p. 588

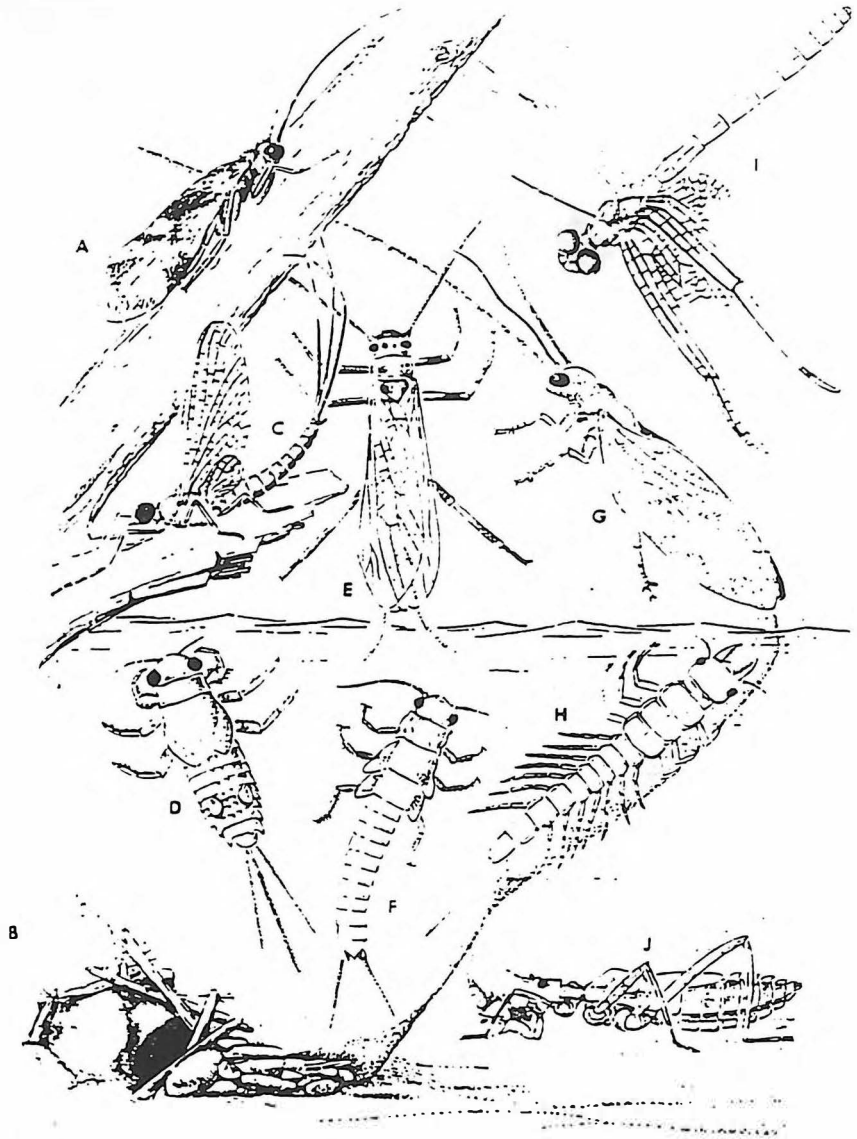


Figure 3-8
Representatives of five orders of aquatic insects. Trichoptera: **A,** adult *Hydroptyche*. **B,** case and net of larva. Ephemeroptera: **C,** adult *Ephemerella*; **D,** naiad or nymph of same genus. Plecoptera: **E,** adult *Isoperla*; **F,** naiad or nymph, *Pteronarcys*. Neuroptera: **G,** adult *Sialis*. **H,** larva, same genus. Odonata: **I,** adult *Macromia*; **J,** naiad or nymph, same species, feeding on *Ephemerella* naiad.

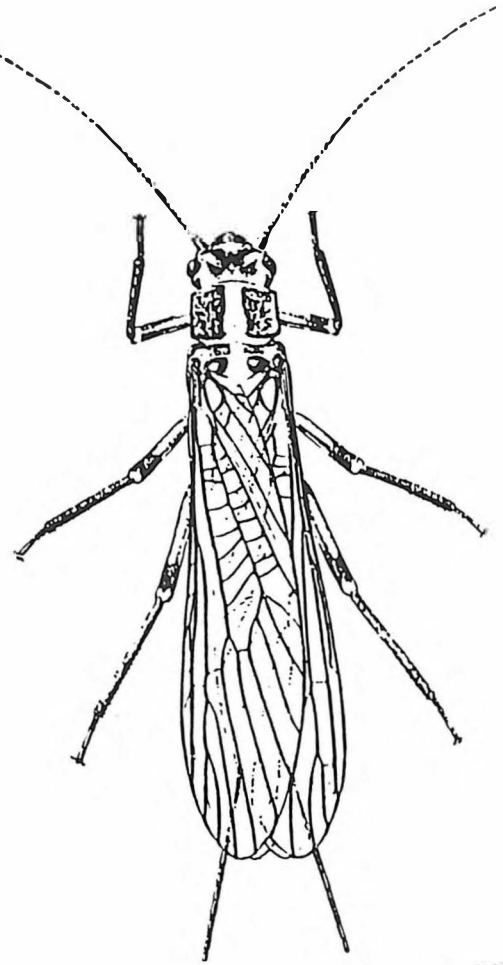
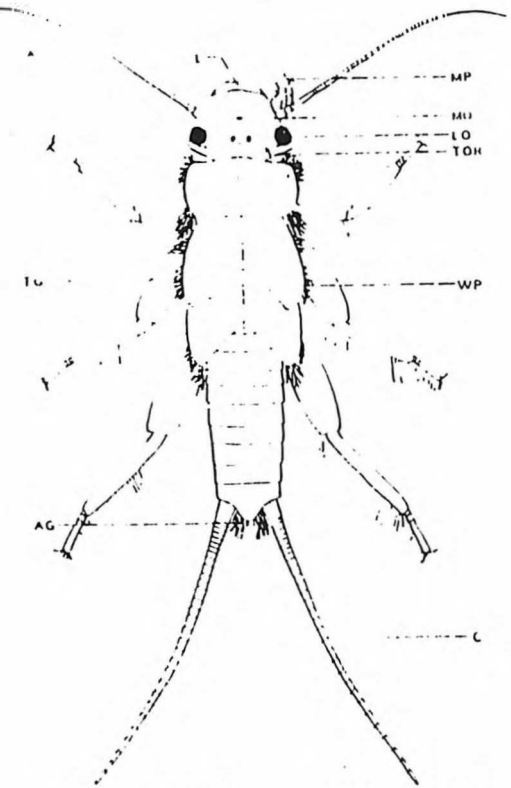


Fig. 310.—Typical adult stonefly, *Isoperla confusa* Frison, ×4.5. (Courtesy Illinois Natural History Survey.)

Stoneflies

17



n. 311. Typical stonefly nymph. A, antenna; AG, anal gills; C, cercus; L, labrum; LO, ral ocellus; MO, median ocellus; MP, maxillary palp; PG, thoracic gills; TOR, transverse spinal ridge; WP, wing pad. (Modified from Frison, 1935.)

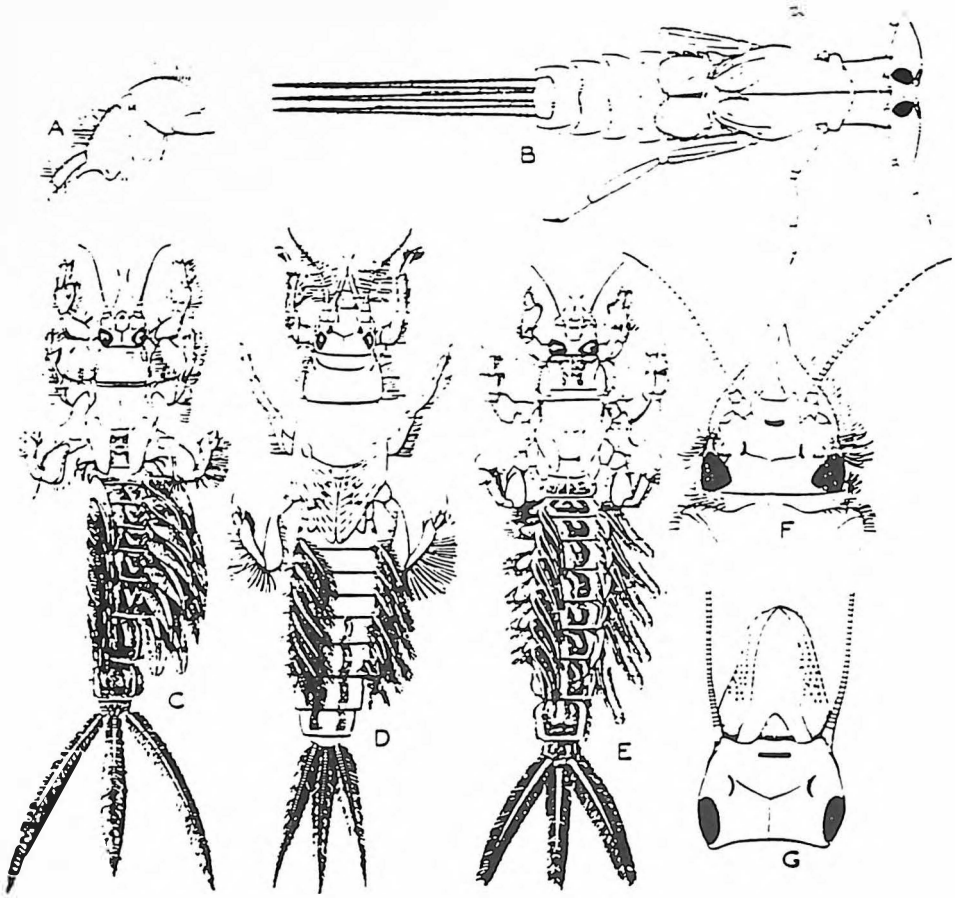


FIG. 316.—Structure of Ephemeridae nymphs. A, foreleg of *Hexagenia bilineata* Say; B, *Orcianthus purpureus* Traver, ×3.5; C, *Hexagenia bilineata*, ×2; D, *Ephemera varia* Eaton, ×4; E, *Pentagenia vittigera* Walsh, ×3; F, head of *P. vittigera*; G, head of *Ephoron*. (A and C to E from Needham, 1920; B modified from Traver, 1931; F modified from Needham, 1920; G modified from Ide, 1935.)

Mayflies

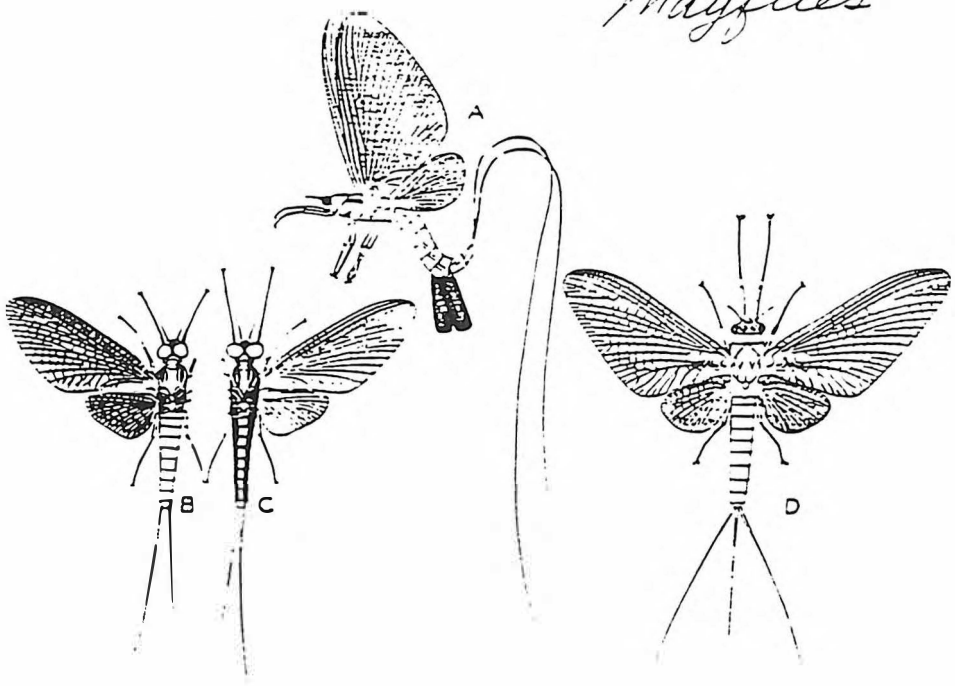


FIG. 317.—Adult mayflies. A, female *Ephoron album* Say with extruded egg packets, ×2;

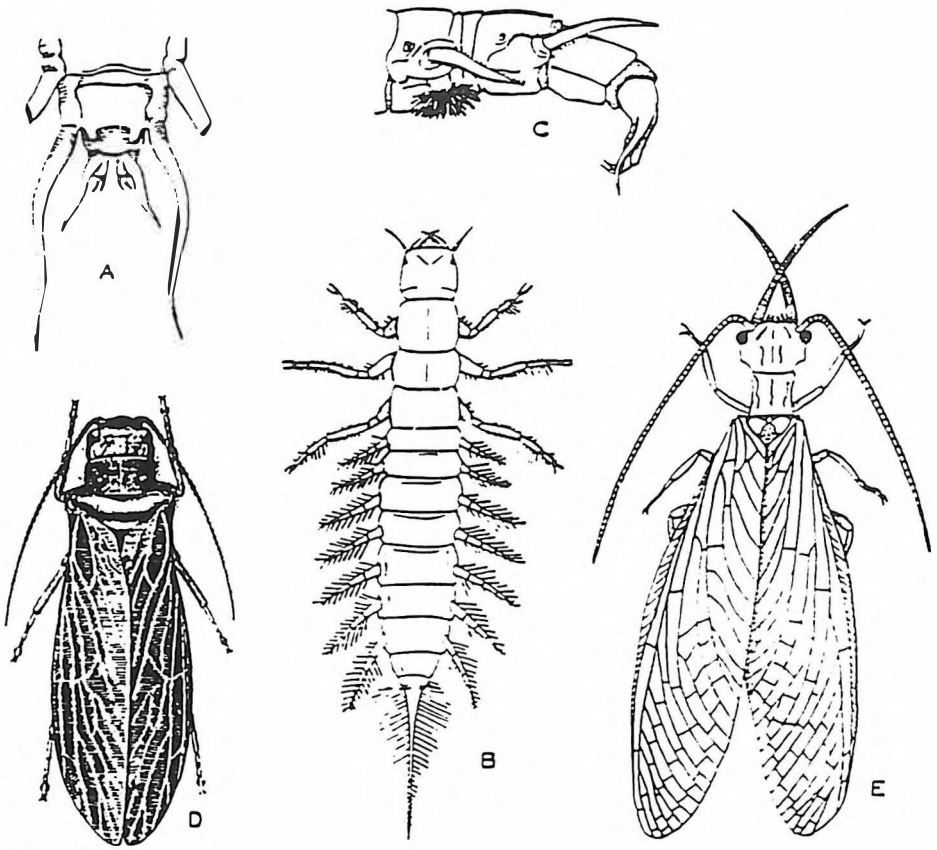


FIG. 348.—Structure of Megaloptera. A, dorsal view of posterior end of *Chauliodes* larva showing proleg; B, dorsal view of *Sialis* larva, ×3; C, lateral view of posterior end of *Corydalus cornutus* L. showing prolegs, spiracles, and tracheal gills; D, adult *Sialis*, ×5; E, adult male *Corydalus cornutus* showing enormously developed mandibles, ×1.2. (D from Ross; B modified from Ross; A and C modified from Snodgrass, 1935.)

Hellgrammite Lobson Fly,

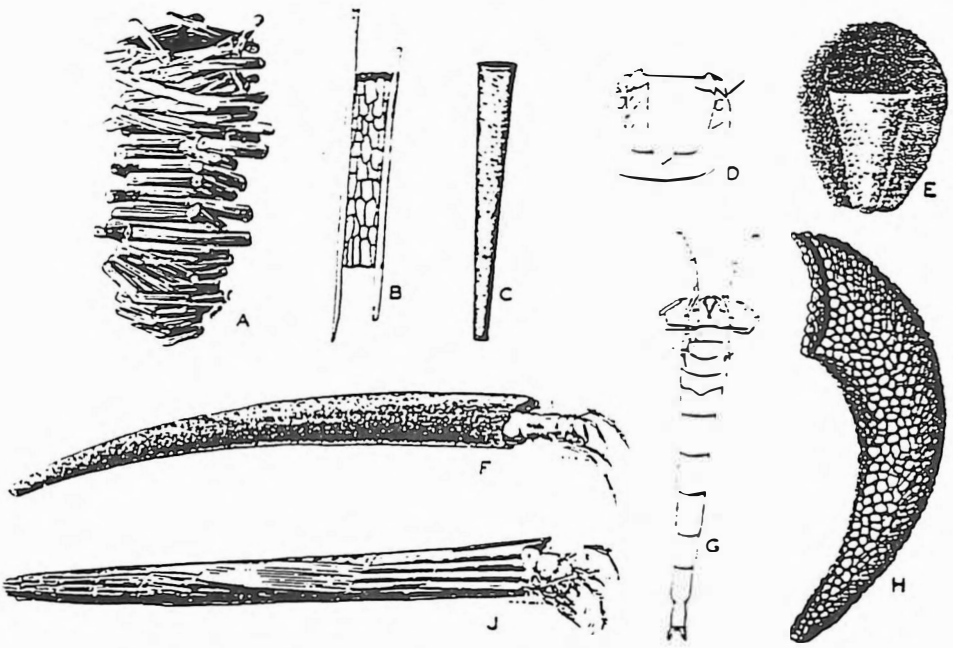
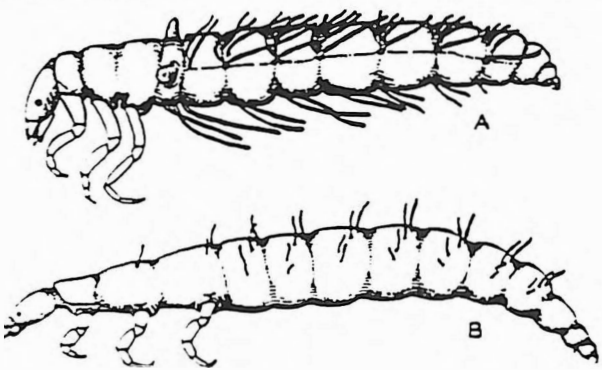


FIG. 359.—Structure of Leptoceridae larvae. A, case of *Oecetis cinerascens* (Hagen), ×6; B, case of *Mystacides sepulchralis* Walker, ×2.5; C, case of *Leptocerus americanus* (Banks), ×3.5; D, head of *Athripsodes*; E, case of *Athripsodes*, ×3.5; F, *Leptocella albida* (Walker), ×4; G, *L. albida*, ×3; H, case of *Athripsodes ancylus* (Vorhies), ×8; J, *Triaenodes tarda* Milne, ×6. (A, E, F, and J from Ross, 1944, courtesy Illinois Natural History Survey; C and H from Lloyd, 1921; D redrawn from Ross, 1944; G from Elkins.)

Caddis Flies



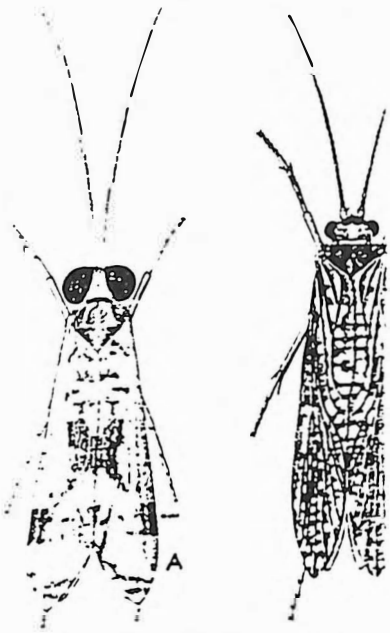


FIG. 360.—Adult caddis flies. A, *Hydrops*
gerata Ross, ×5.5; B, *Rhyacophila fenestra*

Dragonflies & Damselflies

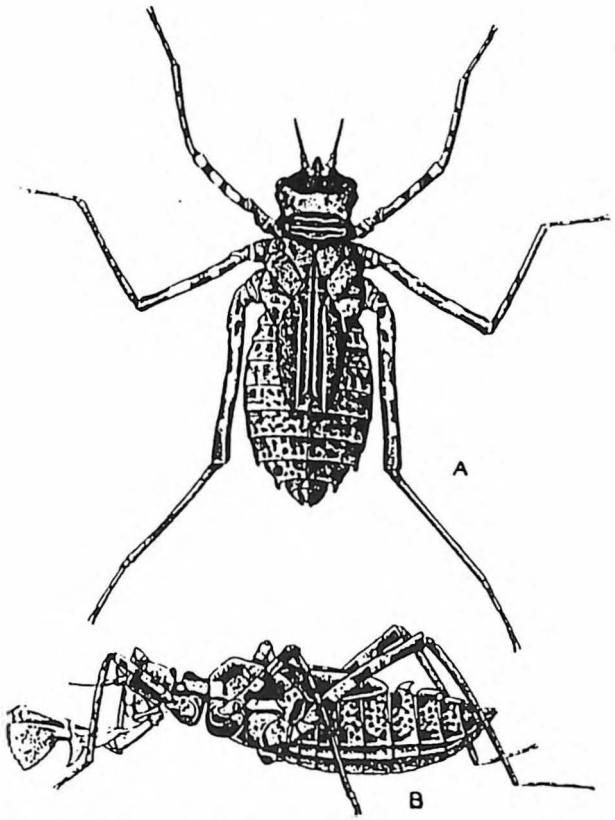


FIG. 321.—Nymph of *Macromia magnifica*, × 1.6. A, dorsal view; B, lateral view with labium ended. (From Kennedy, 1915.)

I may have 3 long feathery caudal filaments, which are gill extensions.

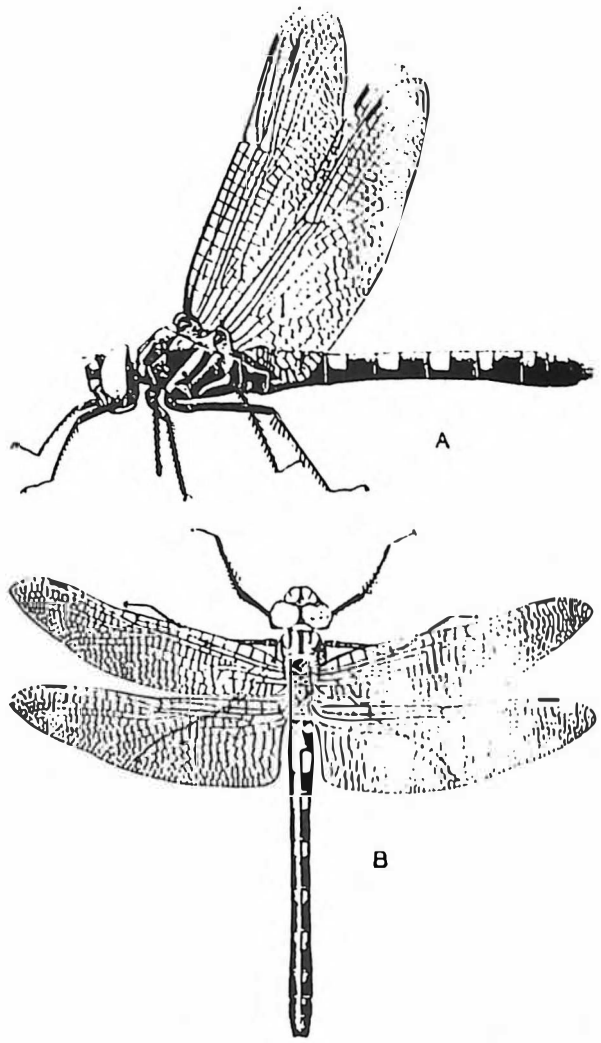


FIG. 321.—Adult dragonfly, *Macromia magnifica* MacLach., × 1. A, lateral view, B, dorsal view. (From Kennedy, 1915.)

SAMPLING SITE CONDITIONS

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 15, 1998 (Sunday)

Approximate Sampling Time: 1500-1630

Air Temperature: 67°F

Weather Conditions: The weather conditions were warm and partly sunny. A slight breeze blew periodically during the sampling time.

Precipitation: N/A

Amount: N/A

Water Temperature: 52° F

Water pH: 4.0

Dissolved Oxygen Level: 7ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 1

~~Location:~~ Dry Run (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: November 29, 1998 (Sunday)

Approximate Sampling Time: 1400-1630

Air Temperature: 65° F

~~Weather Conditions:~~ The weather conditions were clear and sunny. A slight breeze was present during most of the sampling time.

Precipitation: N/A

Amount: N/A

Water Temperature: 53° F

Water pH: 4.5

Dissolved Oxygen Level: 11ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 1

~~Location:~~ Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date ~~of Sampling:~~ December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Air Temperature: 42°F

Weather Conditions: The weather conditions were sunny and calm with no wind blowing

Precipitation: N/A

Amount: N/A

Water Temperature: 54°F

Water pH: 4.5

Dissolved Oxygen Level: 8 ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Air Temperature: 42° F

Weather Conditions: The weather conditions were sunny and calm, with no wind blowing throughout the duration of sampling.

Precipitation: N/A

Amount: N/A

Water Temperature: 55° F

Water pH: 4.5

Dissolved Oxygen Level: 7 ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 2

~~Location:~~ Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: January 17, 1999 (Sunday)

Approximate Sampling Time: 1430-1615

Air Temperature: 48°

Weather ~~Conditions:~~ The weather conditions were sunny and cool. There was a slight breeze, which blew throughout the duration of sampling.

Precipitation: N/A

Amount: N/A

Water Temperature: 46°

Water pH: 4

Dissolved Oxygen Level: 7ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100 - 1500

Air Temperature: 42°F

Weather Conditions: The weather conditions were sunny and calm with no wind present throughout the duration of sampling.

Precipitation: N/A

Amount: N/A

Water Temperature: 57°F

Water pH: 4.5

Dissolved Oxygen Level: 6ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 3

~~Location:~~ Frank's Bottom (Rockingham County Virginia)

Latitude/Longitude:

Date ~~of Sampling:~~ December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Air Temperature: 46°F

Weather Conditions: The weather conditions were cloudy with occasional sprinkles.

Precipitation: Rain

Amount: Sprinkles

Water Temperature: 42°F

Water pH: 4.5

Dissolved Oxygen Level: 10ppm

Additional Comments:

SAMPLING SITE CONDITIONS

Site #: 3

Location: Frank's Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: January 17, 1999 (Sunday)

Approximate Sampling Time: 1430-1615

Air Temperature: 48°

Weather Conditions: The weather conditions were sunny and cool. There was a slight breeze, which blew throughout the durahon of sampling.

Precipitation: N/A

Amount: N/A

Water Temperature: 48°

Water pH: 4.5

Dissolved Oxygen Level: 7 ppm

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 15, 1998 (Sunday)

Approximate Sampling Time: 1500-1630

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	33
Hellgrammite	Megaloptera	1
Mayfly	Ephemeroptera	2
Stonefly	Plecoptera	4

Total Caught: 40

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 29, 1998 (Sunday)

Approximate Sampling Time: 1400-1630

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	15
Mayfly	Ephemeroptera	4
Stonefly	Plecoptera	6

Total Caught: 25

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 1

~~Location:~~ Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	28
Mayfly	Ephemeroptera	3
Stonefly	Plecoptera	4

Total Caught: 35

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	38
Mayfly	Ephemeroptera	15
Stonefly	Plecoptera	16
Stonefly (different species)	Plecoptera	1

Total Caught: 70

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: January 17, 1999 (Sunday)

Approximate Sampling Time: 1430-1615

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	30

Total Caught: 30

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date ~~of Sampling~~: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species:

Common Name	Order	# Caught and Identified
Mayfly	Ephemeroptera	1

Total Caught: 1

Additional Comments:

MACROINVERTEBRATE LOG

Site #: 3

Location: Frank's Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: January 17, 1999 (Sunday)

Approximate Sampling Time: 1430-1615

Species:

Common Name	Order	# Caught and Identified
Caddisfly	Trichoptera	87
Mayfly	Ephemeroptera	5
Stonefly	Plecoptera	7

Total Caught: 99

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 15, 1998 (Sunday)

Approximate Sampling Time: 1500-1630

Species: Salvelinus fontinalis

Fish #: 1

Length: 6"

Weight: 29.34g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.16g

Weight of Stomach Contents: 0.07g

Contents:

Identification	Number Observed
9-spotted ladybug (Order Coleoptera)	1
unidentifiable dipteran (Order Diptera)	1
unidentifiable true bug (Order Hemiptera)	1

Additional Comments: The unidentifiable true bug had eyes that were wider than the thorax, and the orientation of the mouthparts was indistinguishable.

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 15, 1998 (Sunday)

Approximate Sampling Time: 1500-1630

Species: Salvelinus fontinalis

Fish #: 2

Length: 6"

Weight: 30.97g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 1.03g

Weight of Stomach Contents: 0.05g

Contents:

Identification	Number Observed
Incompletely metamorphosized stonefly larva (Order Plecoptera)	1
unidentifiable true bug (Order Hemiptera)	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 15, 1998 (Sunday)

Approximate Sampling Time: 1500-1630

Species: Salvelinus fontinalis

Fish #: 3

Length: 6"

Weight: 27.56g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 1.05g

Weight of Stomach Contents: 0.08g

Contents:

Identification	Number Observed
stonefly larva (Order Plecoptera)	1
grasshopper larva (Order Orthoptera)	1
ground beetle (Order Coleoptera)	1
unidentifiable dipteran (Order Diptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: November 29, 1998 (Sunday)

Approximate Sampling Time: 1400-1630

Species: Salvelinus fontinalis

Fish #: 4

Length: 6"

Weight: 24.83g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.17g

Weight of Stomach Contents: 0.21g

Contents:

Identification	Number Observed
9-spotted ladybug (Order Coleoptera)	2
mayfly larva (Order Ephemeroptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 5

Length: 5 3/8"

Weight: 19.80g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 0.90g

Weight of Stomach Contents: 0.12g

Contents:

Identification	Number Observed
Wood weevil (Order Coleoptera)	1
unidentifiable beetle (Order Coleoptera)	1
unidentifiable insect parts	1
plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 6

Length: 5 3/4"

Weight: 25.77g

Sex: Female

Eggs: ≈250

Mass: 1.23g

Weight of Stomach: 2.06g

Weight of Stomach Contents: 0.85g

Contents:

Identification	Number Observed
unidentifiable small fish	1
stonefly larva (Order Plecoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 7

Length: 7 1/4"

Weight: 50.47g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 2.55g

Weight of Stomach Contents: 1.04g

Contents:

Identification	Number Observed
unidentifiable grasshopper leg (Order Orthoptera)	1
grasshopper (Order Orthoptera)	1
crayfish pincers	2
mayfly larva (Order Ephemeroptera)	2
unidentifiable insect wings	2

Additional Comments: The one grasshopper leg did not belong to the other grasshopper found, which had all legs.

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 8

Length: 6 3/4"

Weight: 49.60g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.00g

Weight of Stomach Contents: 0.03g

Contents:

Identification	Number Observed
mayfly larva (Order Ephemeroptera)	1
stonefly larva (Order Plecoptera)	1
hellgrammite (Order Megaloptera)	1

Additional Comments:

SAMPLE LOG

Site #: 1

~~Location:~~ Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 9

Length: 7¼"

Weight: 49.45g

Sex: Male

Eggs: N/A

~~Mass:~~ N/A

Weight of Stomach: 0.85g

Weight of Stomach Contents: 0.02g

Contents:

Identification	Number Observed
grasshopper head (Order Orthoptera)	1
stonefly larva (Order Plecoptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 1

Location: Dry Run (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 10

Length: 6 1/4"

Weight: 31.28g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 1.21g

Weight of Stomach Contents: 0.01g

Contents:

Identification	Number Observed
unidentifiable plant tissue	1

Additional Comments: This stomach was basically empty, only one small piece of plant material was found.

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date ~~of Sampling~~: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 1

Length: 6"

Weight: 27.07g

Sex: Male

Eggs: N/A

~~Mass~~: N/A

Weight of Stomach: 1.08g

Weight of Stomach Contents: 0.28g

Contents:

Identification	Number Observed
unidentifiable dipteran (Order Diptera)	1
unidentifiable beetle (Order Coleoptera)	1
unidentifiable plant tissue	1

Additional Comments: The contents of this stomach seemed to be much more digested than as was seen in other stomachs. Identification was very difficult with this stomach and its contents.

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 2

Length: 4½"

Weight: 12.55g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 0.55g

Weight of Stomach Contents: 0.09g

Contents:

Identification	Number Observed
arachnid	1
unidentifiable orthopteran (Order Orthoptera)	1
unidentifiable true bugs (Order Hemiptera)	3
stonefly larva (Order Plecoptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 3

Length: 6 1/4"

Weight: 34.68g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.48g

Weight of Stomach Contents: 0.45g

Contents:

Identification	Number Observed
unidentifiable beetle head/mouth (Order Coleoptera)	1
unidentifiable beetle shells (Order Coleoptera)	3
arachnid	1
unidentifiable winged insect	1
ground beetle (Order Coleoptera)	1
ant	1
unidentifiable roundworms	5
small grasshopper (Order Orthoptera)	1
mayfly larva (Order Ephemeroptera)	3
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of ~~Sampling~~: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 4

Length: 4 1/4"

Weight: 9.78g

~~Sex~~: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 0.27g

Weight of Stomach Contents: 0.04g

Contents:

Identification	Number Observed
stonefly larva (Order Plecoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 5

Length: 6"

Weight: 30.85g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.42g

Weight of Stomach Contents: 0.37g

Contents:

Identification	Number Observed
unidentifiable white roundworms	20
grasshopper legs (Order Orthoptera)	2
mayfly parts (Order Ephemeroptera)	3
unidentifiable dipterans (Order Diptera)	2
ground beetle shell (Order Coleoptera)	1
unidentifiable insect heads	3
unidentifiable plant tissue	1

Additional Comments: All three of the unidentifiable insect heads had mouthparts that were turned back.

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 6

Length: 5½"

Weight: 20.85g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 0.74g

Weight of Stomach Contents: 0.01g

Contents:

Identification	Number Observed
unidentifiable plant tissue	1

Additional Comments: This stomach was basically empty, only one small piece of plant tissue was found.

SAMPLE LOG

Site #: 2

~~Location:~~ Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 7

Length: 4½"

Weight: 13.54g

Sex: Male

~~Eggs:~~ N/A

Mass: N/A

Weight of Stomach: 0.69g

Weight of Stomach Contents: 0.19g

Contents:

Identification	Number Observed
grasshopper head/thorax (Order Orthoptera)	1
unidentifiable brown beetle (Order Coleoptera)	1
stonefly larva (Order Plecoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 8

Length: 4½"

Weight: 13.35g

Sex: Female

Eggs: 52

Mass: 1.85g

Weight of Stomach: 0.52g

Weight of Stomach Contents: 0.10g

Contents:

Identification	Number Observed
grasshopper legs/parts (Order Orthoptera)	3
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 9

Length: 4 1/8"

Weight: 9.45g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 0.33g

Weight of Stomach Contents: 0.02g

Contents:

Identification	Number Observed
unidentifiable plant tissue	1

Additional Comments: The material in this stomach was very digested. Identification was difficult.

SAMPLE LOG

Site #: 2

Location: Slate Hole (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 10

Length: 6 1/4"

Weight: 35.74g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 1.03g

Weight of Stomach Contents: 0.14g

Contents:

Identification	Number Observed
grasshopper (Order Orthoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998 (Saturday)

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 1

Length: 4½"

Weight: 10.62g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 0.29g

Weight of Stomach Contents: 0.01g

Contents:

Identification	Number Observed
mayfly larva (Order Ephemeroptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Frank's Bottom (Rockingham County Virginia)

Latitude/Longitude:

Date of Sampling: December 5, 1998

Approximate Sampling Time: 1100-1500

Species: Salvelinus fontinalis

Fish #: 2

Length: 8 1/4"

Weight: 75.24g

Sex: Female

Eggs: 43

Mass: 2.43g

Weight of Stomach: 1.73g

Weight of Stomach Contents: 0.00g

Contents:

Identification	Number Observed

Additional Comments: This stomach was completely empty.

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 3

Length: 5 3/4"

Weight: 20.32 g

Sex: Female

Eggs: ≈100

Mass: 0.17g

Weight of Stomach: 0.69 g

Weight of Stomach Contents: 0.03 g

Contents:

Identification	Number Observed
mayfly larva (Order Ephemeroptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 4

Length: 5"

Weight: 15.44g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 0.47g

Weight of Stomach Contents: 0.02g

Contents:

Identification	Number Observed
Unidentifiable insect head	1
mayfly larva (Order Ephemeroptera)	1

Additional Comments: The insect head/thorax had eyes that were the same width as the thorax and long antenna.

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of ~~Sampling~~: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 5

Length: 8 1/8"

Weight: 57.42g

Sex: Female

Eggs: 4

Mass: 0.17g

Weight of Stomach: 2.12g

Weight of Stomach Contents: 0.16g

Contents:

Identification	Number Observed
mayfly larva (Order Ephemeroptera)	1
unidentifiable plant tissue	1
caddisfly larva (Order Trichoptera)	1
unidentifiable black beetle (Order Coleoptera)	1
ground beetle (Order Coleoptera)	1
grasshopper (Order Orthoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Frank's Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 10

Length: 6"

Weight: 30.36g

Sex: Female

Eggs: 12

Mass: 1.80g

Weight of Stomach: 1.48g

Weight of Stomach Contents: 0.19g

Contents:

Identification	Number Observed
grasshopper (Order Orthoptera)	1
unidentifiable brown beetle (Order Coleoptera)	1
unidentifiable fly (Order Diptera)	1
stonefly larva (Order Plecoptera)	1
unidentifiable plant tissue	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 7

~~**Length:**~~ 6 3/4"

Weight: 49.71g

Sex: Female

Eggs: ≈300

Mass: 8.90g

Weight of Stomach: 2.06g

Weight of Stomach Contents: 0.05g

Contents:

Identification	Number Observed
unidentifiable insect head/thorax	1
unidentifiable aquatic insect	1
grasshopper leg (Order Orthoptera)	1

Additional Comments: The unidentifiable insect head had eyes that were wider than the thorax.

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date ~~of Sampling~~: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 8

Length: 7"

Weight: 48.21g

Sex: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 1.79g

Weight of Stomach Contents: 0.09g

Contents:

Identification	Number Observed
unidentifiable plant tissue	1
caddisfly larva (Order Trichoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of ~~Sampling~~: December 12, 1998 (Saturday)

Approximate Sampling Time: 1430-1630

Species: Salvelinus fontinalis

Fish #: 9

Length: 8 3/4"

Weight: 78.31g

~~Sex~~: Male

Eggs: N/A

Mass: N/A

Weight of Stomach: 3.37g

Weight of Stomach Contents: 0.31g

Contents:

Identification	Number Observed
grasshopper (Order Orthoptera)	1

Additional Comments:

SAMPLE LOG

Site #: 3

Location: Franks Bottom (Rockingham County, Virginia)

Latitude/Longitude:

Date of Sampling: January 17, 1999 (Sunday)

Approximate Sampling Time: 1430-1615

Species: Salvelinus fontinalis

Fish #: 10

Length: 6 3/4"

Weight: 49.89g

Sex: Male
Eggs: N/A
Mass: N/A

Weight of Stomach: 1.39g

Weight of Stomach Contents: 0.02g

Contents:

Identification	Number Observed
stonefly larva (Order Plecoptera)	1

Additional Comments: