STAGE 2—EXPLORE, DISCOVER, CREATE

Field Data Collection (physical, chemical, and biological)

The second stage of the teaching/learning model focuses on investigating the research problem scenario. Here, you provide students with the materials, methods, and procedures they need to observe, collect data, and begin organizing information.

Teacher Tips

1. Field data collection activities will acquaint students with procedures to determine the relative pollution index for a particular reach of a stream and how it compares to standards (using a Field Biotic Index).
2. As part of the data collection activity, teachers should review the methods and procedures in the classroom and take the time at the stream site to review the information.
3. To establish study sites, select a good study section on a stream. It is important that you spend time at the stream before you take your students on the field trip. Make sure you perform all the tests so you know what to expect, especially in the way of invertebrates. The study reach should be typical of the stream and include different types of habitat, such as riffles and pools, which when taken together and sampled, will give a representative picture of the river.
4. Select two study sites: one above and one below the town or area that may cause a pollution problem (irrigation canal return). Ideally, the physical characteristics of the sampling sites should be as similar as possible (riparian vegetation, substratum, stream volume, velocity). For each site, establish three transects within a 100-meter reach to characterize different habitats (Transects A, B, and C for the upreach, downreach, and midreach, (see Figure 5.6). Picture each transect as a cross-section that will look something like Figure 5.7.

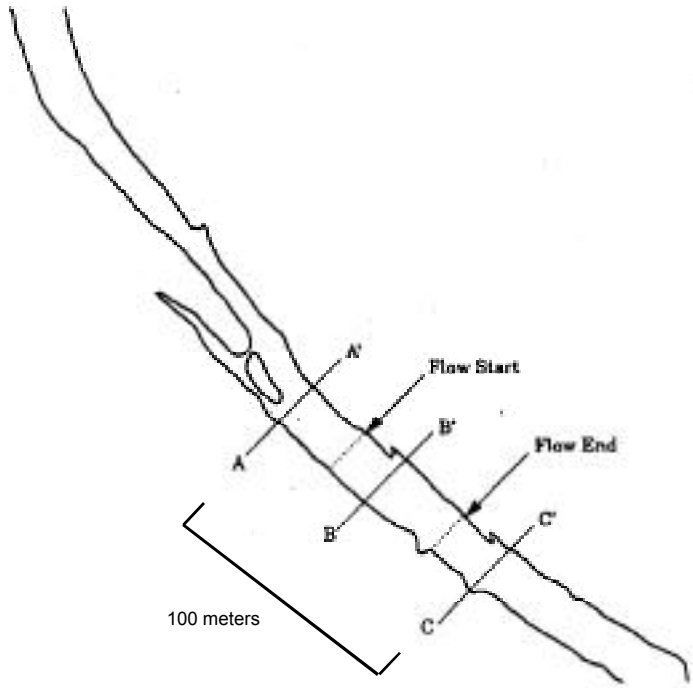


Figure 5.6. River Study Transects

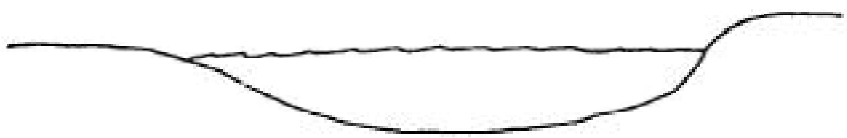


Figure 5.7. River Transect Cross-Section

Activity: Collecting Field Data

Learning Outcomes

By the end of the activity students will have:

- collected aquatic insects
- measured physical and chemical variables of streams
- gained a basic understanding of how stream ecosystems function.

Materials/Equipment

Physical Data Teams

- Laboratory notebook, 1 per student
- Data sheets (included in Attachment 2)
- Meter stick, 1 per team
- 100-m tape, 1 per team
- 10- to 20-m tape, 1 per team
- Stopwatch, 1 per team
- Oranges or marshmallows, 1-2 per team

Chemical Data Teams

- Laboratory notebook, 1 per student
- Data sheets (included in Attachment 3)
- pH kit, 1 per team
- Alkalinity kit or pH indicators, 1 per team
- Dissolved oxygen monitor, 1 per team

Biological Sampling Teams

- Laboratory notebook, 1 per student
- Collecting nets (see Figure 5.8), 1 per team
- Sorting trays (ice cube trays), 2 per team
- Surber/Screen samplers (see Figure 5.9) 1 per team
- Forceps or tweezers, 1 per student

Figure 5.8. Collecting Net

- Data sheets (included in Attachment 4)
- Vials and jars
- Trowel
- Labels
- Isopropyl alcohol
- Macroinvertebate key (see Attachment 5), 1 per team

Procedure

1. Travel to first study site.
2. Have the students describe in their journals the first study site. Take a moment to discuss their entries. Discuss with your students how the setting can be described in terms of its physical, chemical, and biological characteristics.
3. Review the investigative procedures and methods research teams will use to yield needed information (physical, chemical, biological). Students should record this information in their journals if they did not do so in class.
4. Practice skills needed for collecting field data. Demonstrate how to collect insect samples and take physical and chemical measurements.
5. Assign students to one of three research teams (physical, chemical, or biological). For example, if you had 27 students, you could assign 15 students (5 teams) to collect insects, 6 students (1-2 teams) to make physical measurements, and 6 students (1-2 teams) to make chemical measurements.

Team 1: Collecting Physical Data *(stream width, stream depth, velocity, volume, and substratum size)*

- Have students draw a schematic map of the study reach in their laboratory journal, showing such things as pools, riffles, logs, large boulders, or any other unusual features. Note each study transect.
- In the 100-meter study reach students have established, determine average **stream width** by measuring width of stream at the upreach (A), downreach (B), and midreach (C), as shown in Figure 5.6. Record data on physical data sheet (Attachment 2).

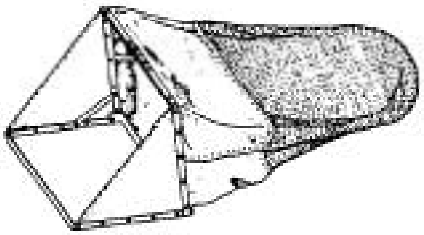


Figure 5.9. Screen Sampler

- Determine average **stream depth** by measuring depth in five places (see Figure 5.6) (the left edge, right edge, middle, one point between the left edge and middle, and one point between the right edge and middle) and at each place the width was determined. Record on data sheet. NOTE: Do not have your students wade to the center of the stream if it is fast moving or wide. Spring melt can change the velocity and width of a stream very quickly. If students cannot take all the depth measurements, brainstorm with them how they might be able to find this information (i.e., local fisherman, family that lives along the stream, estimating based on the slope of the steam bottom).
- Determine average **substratum size** by stretching the measuring tape across the stream. At 1-foot intervals along the tape, place meter stick vertically into the stream. Measure the longest dimension of whatever rocks the meter stick touches. Using that number, calculate the mean substream size. Record on physical data sheet. Students should brainstorm why substratum size is important.
- Determine **stream flow velocity** and **stream flow volum** e using the following methods.

Stream Flow Velocity

a. Choose a length of the study reach as long as possible that has the same conditions (long riffle—minimum 150 feet). Measure this length, and mark the beginning and end. If possible, the reach should be located at a site where a stream transect contour was done.

b. Have one student drop a suitable float (such as an orange or large marshmallow) above the beginning of the "test" stretch of the stream. When the float crosses the marked beginning, have another student start the stopwatch. A third student should be stationed at the end point of the "test" stretch (see Figure 5.6). When the float crosses the lower end, the students should tell the timer to stop. Repeat this procedure three times, then determine the average. Record all these calculations on the physical data sheet.

c. Calculate the velocity by dividing the length of the section (in meters) by the time (in seconds) to determine the velocity in meters per second (mps). Record the velocity on the data sheet.

Stream Flow Volume

a. Using the following formula, calculate flow volume.

$$V = \frac{WDLa}{T}$$

where V = volume in cubic feet per second (cfs)

W = average width for the test section in feet

D = average depth of test section in feet

L = length of test section in feet

T = average time for float to go through the test section

a = a constant depending on the type of river bottom. (If the bottom is rocky, use 0.8 as the constant; if it is smooth, use 0.9.)

b. Measure W and D at the two ends and middle of the test section using the same methods described above.

Extensions:

1. Identify an area on a local river or stream that has two tributaries coming together (see Figure 5.10). Have the students determine the Stream Flow Volume for A and B. They should then be able to estimate the Stream Flow Volume for C. Once they have estimated the volume for C, have the students collect the data on the width, depth, and velocity of site C. Using the formula, have them calculate the volume using their data.

2. Identify an area on a local river or stream where it narrows down and curves around a bend (see Figure 5.11). Have the students collect data and calculate the Stream Flow Volume for the stream at site A and again estimate it for site B. Once they have estimated the Stream Flow Volume for A, have them collect the data to calculate the Stream Flow Volume for B.

For both of the extensions, discuss with the class: How do the numbers based on their data compare to their estimate? Why might the numbers be different? What are some of the variables that could influence their answers?

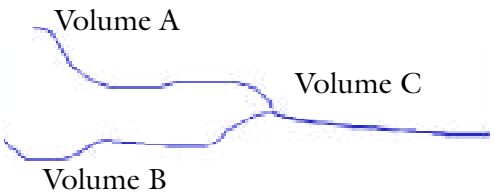


Figure 5.10. Stream with Two Tributaries Coming Together

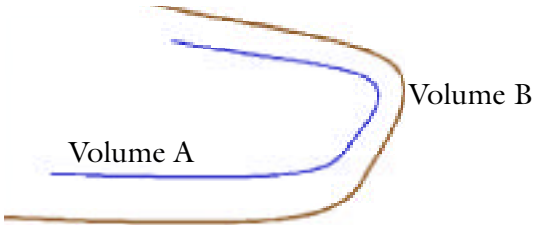


Figure 5.11. Reach of Stream Where Width Narrows and Curves Around a Bend

Team 2: Collecting Chemical Data (dissolved oxygen, pH, and temperature)

- Measure dissolved oxygen concentrations and pH at beginning (head) and end of study reach using directions included in kits.
- Measure water temperature at head and end of study reach, using the thermometer. Record on chemical data sheet.
- Make any comments about the area in your notebook—sun, shade, leaf matter on bottom.

Team 3: Collecting Biological Data

- Working in threes, collect a minimum of 25 aquatic insects per team with nets and by hand picking insects from stones and sticks throughout the study reach. The teams should spread out along the river/stream.
- You can choose to use all of the following techniques or a combination of them.

    a. Kick Net: Wade into the river/stream. One student should place the net into the water while the other stands upstream and agitates the substrate for approximately 30 seconds directly in front of the net to dislodge insects. Students should decide the size of the area they will agitate before entering the stream. They should pick up large rocks and brush or pick off all the organisms. Once the rock is cleaned, discard it outside the "area" determined by team. If the water is shallow enough, students can use a garden trowel to agitate the bottom; if not, they can gently more their feet to dislodge organisms. Once they have determined the area, it should stay consistent in each area as they sample. Remove the net from the water. Take insects collected to shore, and place them in a sorting tray. Using forceps, place as many different kinds of organisms as possible into alcohol-filled specimen jars for later identification in the classroom. Label each jar with upper/lower study site and upreach, downreach, or mid-reach. Repeat the procedure several times until you have collected approximately 100 insects.

    b. Surber Net: A Surber stream sampler can be used it you want to do a quantitative analysis of the steam/river you are studying. The sampler is placed in the stream so that the net is downstream of the frame. The stream/river bottom is agitated inside the frame and the organisms are washed into the net. The Suber sampler is most appropriately used in shallow streams and rivers. Students should pick up larger rocks and debris, and while holding them in front of the net, brush them free of any organisms. Discard the cleaned rocks outside of the frame. Using a garden trowel, agitate the bottom within the frame completely to a uniform depth. Repeat the sampling along the area of the stream being studied. Once all the collecting is done, empty the net contents into a wide-mouth jar and label. Make sure to clean the net completely.

- In your journal, note various ecological characteristics of the study reach, including such things as the amount of riparian vegetation, degree of shading of stream bottom, amount of particulate organic matter on the stream bottom and in the water.

6. After physical, chemical, and biological data have been collected from the first study site, travel to sample site below the town. Have students switch groups. Students who collected physical and chemical data should now collect insects. Students who collected insects should be divided to collect physical and chemical data.

Teacher Tips:

1. Biological monitoring, or biomonitoring, is the use of biological responses to assess changes in the environment, generally changes due to anthropogenic causes.

   Biomonitoring involves the use of indicators, indicator species, or indicator communities. Generally, benthic macroinvertebrates, fish, and/or algae are used. Certain aquatic plants also have been used as indicator species for pollutants, including nutrient enrichment. There are advantages and disadvantages to each. Macroinvertebrates are most frequently used. Biochemical, genetic, morphological, and physiological changes in certain organisms have been noted as being related to particular environmental stressors and can be used as indicators.

   The presence or absence of the indicator or of an indicator species or indicator community reflects environmental conditions. Absence of a species is not as meaningful as it might seem as there may be reasons, other than pollution, that result in its absence (e.g., predation, competition, or geographic barriers which prevented it from ever being at the site). Absence of multiple species of different orders with similar tolerance levels that were present previously at the same site is more indicative of pollution than absence of a single species. It is clearly necessary to know which species should be found at the site or in the system.

   (From: Bartenhagen, K., M.H. Turner, and D.L. Osmond. 1998. *Water Quality Information*. North Carolina State University, Cooperative Extension, Biological, and Agricultural Engineering, Raleigh, North Carolina.)

2. If there is extra time at the study sites, students can began sorting the specimens using the Marcroinvertebrate key. This is a rough sort. Specimens will be identified back in class.

3. The following references are available free from the Washington State Department of Ecology (360-407-7472) and may be useful references for the biological assessment of a stream or river.

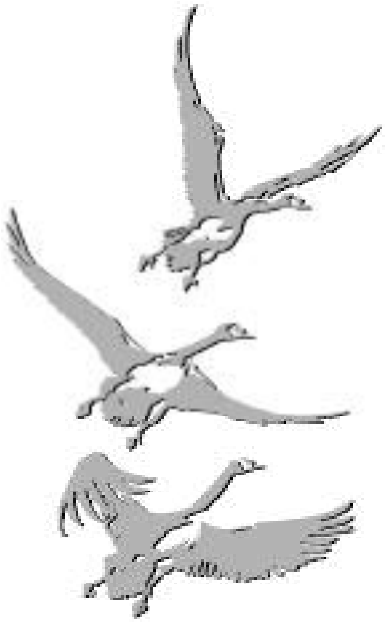
Ambient Monitoring Instream Biological Assessment: Progress Report of 1993 Pilot Survey. Washington Department of Ecology. July 1995. Publication 95-333.

Instream Biological Assessment Monitoring Protocols: Benthic Macroinvertebrates. Washington Department of Ecology. June 1994. Publication 94-113.

Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington State Department of Ecology. Washington Department of Ecology. June 1996. Publication 96-323.

A good reference book:

Handbook or Common Methods in Limnology. Owen Lind. 1985. Kendall/Hunt. Dubuque, Iowa.



Activity: Identifying Macroinvertebrates

Learning Outcomes

By the end of the activity students will have:

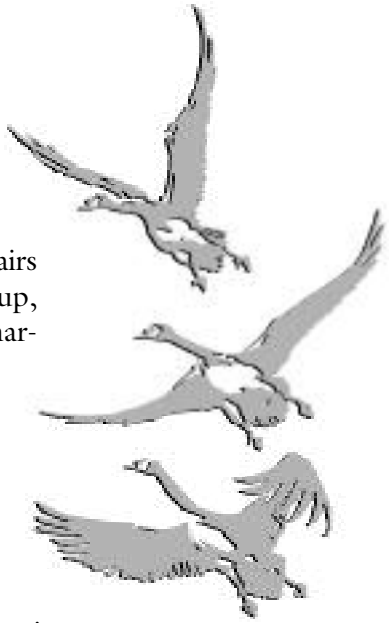
- identified aquatic insects and placed them in functional groups
- determined functional group percentages and what they indicate
- calculated a field biotic index
- learned to use a binomial key to identify freshwater aquatic organisms.

Materials/Equipment

- Binocular dissection microscopes or good hand lenses
- Forceps, tweezers, and teasing needles (bamboo skewers)
- Taxonomic keys for insect orders and families
- Petri dishes/plastic dishes for insects
- Macroinvertebrate data sheet to record the number and kinds of insects

Procedures (all students help with identifying macroinvertebrates)

1. Set up and demonstrate the proper use of microscopes, forceps/tweezers, and teasing needles.
2. Distribute binomial keys (see Attachment 5) or use one of the following books:
    - *An Illustrated Guide to the Mountain Stream Insects of Colorado*, J.V. Ward and B. Kondratieff, 1992, University of Colorado Press, Colorado. Good for middle and high-school students.
    - *The Fisherman's and Ecologists' Illustrated Guide to Insects and Their Relatives*, W. Patrick McCafferty, Jones and Bartlett, Boston, Massachusetts. Good for middle and high-school students.
    - *An Introduction to the Aquatic Insects of North America*, Edited by R.W. Merritt and K.W. Cummins, Kendall/Hunt, Dubuque, Iowa. This is the "bible" of aquatic insect keys, most appropriate for high-school students.
3. If necessary, demonstrate how to use binomial keys. Introduce the concept of binomial keys with an activity called Sport Balls (described in Attachment 6).
4. Using an easily keyed insect, walk students though the identification process.



5. Sort insects into similar groupings. Then, working in pairs using the keys provided, identify one from each group, and assign it to a family. One student presents the characteristic choices in the binomial keys and the other, using the microscope/hand lens, decides which choice to make on the key. Repeat this process until the insect is identified. Students should switch jobs, so both get a chance to use the microscope. Record the family name and number of specimens of that family on the macroinvertebrate data sheet (Attachment 7).

6. Continue until all groups of invertebrates have been identified, or more likely, until time runs out.

7. Calculate a biotic index by using the tolerance values shown in Table 5.4. The values given in Table 5.4 are for rivers and streams in this area of the Pacific Northwest. Values would be different for ponds and for other areas of the region. To find out more about biotic indexes see the following sources.

   Davis, W.S., and T.P. Simon (eds.). 1995. *Biological Assessment and Criteria: Tools for Water Resources Planning and Decision Making.* Lewis Publishers, Boca Raton, Florida.

   Karr, J.R. 1981. "Assessment of Biotic Integrity Using Fish Communities." *Fisheries* 6(6):21-27.

   Karr, J.R., and D.R. Dudley. 1981. "Ecological Perspective on Water Quality Goals." *Env. Mgmt.* 5(1):55-68.

   Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. "Assessing Biological Integrity in Running Waters: A Method and Its Rationale." *Ill. Nat. Hist. Surv. Spec. Publ.* 5. 28 pp.

   Ohio EPA. 1992. *Biological and Habitat Investigation of Greater Cincinnati Area Streams (Hamilton and Clermont Counties, Ohio).* Ohio EPA Technical Report EAS/1992-5-1. Division of Water Quality Planning and Assessment, Columbus, Ohio.

   Ohio EPA. 1992. *Biological and Water Quality Study of the Cuyahoga River and Selected Tributaries.* Ohio EPA Technical Report EAS/1992-12-11. Division of Surface Water, Columbus, Ohio.

8. Compare index with rankings shown in Table 5.5.

Compare your calculated FBI with those in Table 5.5 below to determine the water quality of the study reach:

Table 5.4. Calculating a Field Biotic Index (FBI)

Tolerance Index :

Plecoptera (Stonefly Families): Chloroperlldae-1; Perlidae-1; Perlodidae-2; Pteronarcyidae-0

Ephemeroptera (Mayfly Families): Baetidae-4; Ephemereilidae-1; Heptagenlidae-4; Leptophlebilidae-2: Siphlonuridae-7

Odonata (Drangonfly Families): Coenagrionidae-9; Lestidae-9

Trichoptera (Caddisfly Families): Brachycentridae-1; Glossosom atidae-O: Hydropsychidae-4; Lepidostomatidae-1; Leptoceridae-4; Limnephilidae-4; Philopotomidae-3; Rhyaoophilidae-O

Calculation of FBI :

Family Name	Number	x	Tolerance Index	=	Value
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
	Sum =		Sum	=	

Sum of values + sum of number of insects = FBI

Table 5.5. Determining Water Quality

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Activity: Analyzing and Summarizing Data

Teacher Tip

1. What do we know? This activity summarizes what students "know" about the biological, chemical, and physical characteristics of the stream. Using data collected at the river and results of the laboratory tests, the students, the teacher, and a visiting scientist meet as a group to summarize what they found. Discussion not only deals with understanding the results obtained from tests but also focuses on their reliability and applicability to the problem.

Procedure

1. Teams that collected physical and chemical data record numbers on a whiteboard, overhead, or flip chart. The group discusses what the physical and chemical data (see Attachment 8 for pH and temperature information) mean in the context of the overall research problem scenario. Note: This is where it is important to have an experienced aquatic ecologist help lead the discussion. Likely, there is not one simple answer for what the data mean. You also can have students research this area. Some references (including web sites) are provided below:

   Cushing, C.E., K.W. Cummins, and G.W. Minshall (eds). 1995. *Ecosystems of the World: River and Stream Ecosystems*, Vol. 22, Elseivier, Amsterdam.

   Washington Department of Fish and Wildlife (WDFW). 1997. *Nature Mapping for Fish and Streams: A Citizen's Guide to Stream Monitoring and Restoration*, WDFW, Outreach and Education, Olympia, Washington.

   Washington Department of Fish and Wildlife (WDFW). 1997. *Catalog of Selected Education Materials Designed to Promote Environmental Education*, WDFW, Ecosystems Education, Olympia, Washington.

   Yates, S. 1988. *Adopting a Stream: A Northwest Handbook*. Adopt-a-Stream Foundation, University of Washington Press, Seattle, Washington.

   Web Sites

   Water Sheds http://h2osparc.wq.ncsu.edu/

   WWW Water Resources (Water Quality) http://www5.bae.ncsu.ed/programs/extension/wqg/issues/resources.html

2. All groups summarize insect data and "build" a table on the board that displays all the data. What emerges is that insects are a key indicator of the health of a stream.

3. Discuss with students how what they know relates to the original question.