Alice Ferguson Foundation's

BRIDGING THE WATERSHED

WATER CANARIES

Assessing Benthic Macroinvertebrates

An outreach program of the Alice Ferguson Foundation in partnership with the National Park Service and area schools that offers secondary school students opportunities to study real-world science in national parks.

Teacher's Guide & Resources

WATER CANARIES

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MODULE ORGANIZER

This module is divided into three sections: activities completed prior to the park visit (Pre-Field Study), activities conducted in the park (Field Study), and activities completed subsequent to the park visit (Post-Field Study). In the Pre-Field Study activities, students learn about benthic macroinvertebrates and how to identify them in an online interactive activity. Once in the park, students will be able to use identification skills to collect macroinvertebrates from a river or stream. They will learn how certain macroinvertebrates can indicate levels of stream pollution. In the context of collecting authentic data in the park, students gain a deeper understanding of the connection between the choices they make and the water quality in their watershed. When students return to the classroom, they will reflect on their visit to the park and compile a group report that will summarize the data collected. Students will also engage in an activity to understand how the trends in populations of various organisms in the Chesapeake Bay watershed are used to monitor the health of an ecosystem. Afterwards, students complete an action project that addresses an environmental issue in their community and school. Completing all parts of this module will achieve a Meaningful Watershed Educational Experience (MWEE), a learner-centered framework that focuses on investigations into local environmental issues and leads to informed action. This module is designed to ensure that the MWEE is done thoughtfully to increase student environmental literacy.

Note: The teacher guide includes all the lessons, including student pages. The student materials are included with the supplementary materials and can be printed out as needed.

TITLE	GOAL(S)	MATERIALS LIST
PRE-FIELD STUDY		
Macroinvertebrate ID	• To learn how to identify macroinvertebrates. • To understand how benthic macroinvertebrates can be used as biological indicators of water quality.	• Computer with Internet access • PowerPoint presentation worksheets • Dichotomous keys
Make-a-Macro	• To apply understanding of macroinvertebrate adaptations to a critter of student's own design.	• Make-a-Macro cards • Glue • Scissors • Student sheet for describing macro and the conditions under which it will thrive
FIELD STUDY		
Macroinvertebrates: Collect, Classify, and Count	To assess water quality by collecting, classifying, and counting, macroinvertebrates found in a stream.	• Appropriate clothing • Adequate food and drink • All other materials will be provided
POST-FIELD STUDY		
Data Analysis	• To compute the index value of the stream you studied using group data. • To calculate the average index value of the stream using all class data.	• Computer with Internet access
Potomac Confidential	• To understand how the presence of certain organisms can give us information about the health of the environment.	Each student needs: • Copy of Potomac Confidential graphic novel • Pencil/colored pencils to complete the story

Now You See Them; Now You Don't	• To assess the health of three sites on the Potomac River. • To relate macroinvertebrate populations to the degradation of benthic habitat in the Chesapeake Bay watershed. • Consider implications of a chemical spill and its impact on macroinvertebrates in the Potomac.	• Data sheets from field study
Student Action Project: Take Action!	To increase awareness of the need for individual environmental action.	Computer with Internet access
RESOURCES		
These resources will provide additional information on the subjects of all the activities. Teachers may use them as a personal reference, or may assign them to students as further reading.		

NOTE: The overview module, "Potomac River Watershed: Water, Water, Everywhere" contains several activities that introduce the concept of a watershed and nonpoint source pollution that are excellent supplements to this module. "Who Polluted the Potomac?" also in the overview module, provides the basic understanding of nonpoint source pollution.

Next Generation Science Standards (NGSS)

Bridging the Watershed curriculum is correlated to Next Generation Science Standards (NGSS). The table below demonstrates performance expectations and the three dimensions of NGSS: science and engineering practices, disciplinary core ideas, and crosscutting concepts.

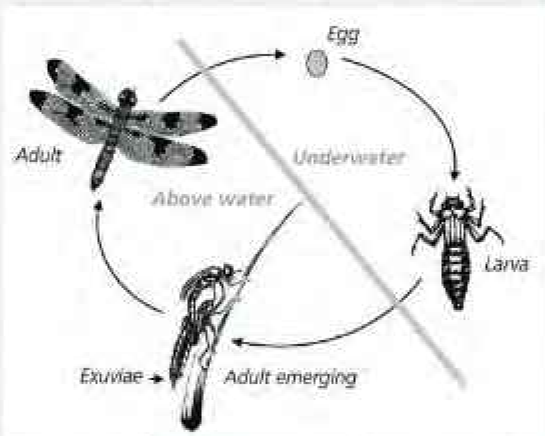
Performance Expectations	
MS-LS2-4	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-LS2-5	Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
MS-ETS1-3	Analyze and interpret data to determine similarities and differences in findings among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
HS-ESS2-5	Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Constructing Explanations and Designing Solutions • Analyzing and Interpreting Data • Engaging in Argument from Evidence • Constructing Explanations and Designing Solutions • Planning and Carrying out Investigation	• LS2.C Ecosystem Dyanmic, Functioning, and Resilience • LS4.D: Biodiversity and Humans • ETS1.B Developing Possible Solutions • ETS1.C Optimizing the Design Solution • ESS2.C The Roles of Water in Earth's Surface Processes	• Stability and Change • Cause and Effect • Structure and Function

Introduction to Water Canaries

BACKGROUND INFORMATION:

Benthic macroinvertebrates are bottom-dwelling organisms that inhabit aquatic environments, have no backbones, and are large enough to see with the naked eye. These organisms include insects, crustaceans, mollusks, and worms, among others. Many of the ones we find are insect larvae or nymphs that start their life in the water before they emerge as terrestrial organisms.



These organisms serve as bioindicators, meaning they are sensitive to disturbances in their habitat. Monitoring their presence or absence tells us something about the level of disturbance, such as water temperature changes, nutrient concentrations, and oxygen levels. Certain species have developed adaptations that allow them to tolerate different levels of disturbance in the water. Macroinvertebrates are typically categorized into three categories: pollution sensitive, somewhat pollution sensitive, and pollution tolerant. A diverse array of macroinvertebrates in all categories suggests a healthy and balanced stream. The variety of benthic macroinvertebrates found in a stream can drastically change over time through climate change, as we experience warmer waters, droughts, and heavier rainfalls.

The title of this module, Water Canaries, refers to the use of these macroinvertebrates to indicate pollution in the stream, in the same way that coal miners once used canaries to indicate the presence of poisonous gases in mines. This module and the field study in the park are designed to heighten students' awareness about the watershed in which they live in and help them understand the important role they play in its health.

Goal:

To learn the scientific concepts of the activities in this module.

Materials:

- Potomac River watershed map
- The Resources section contains reference material needed to complete the activities
- Review the Bridging the Watershed at fergusonfoundation.org

Macroinvertebrate Identification

EXPLORATION

BACKGROUND INFORMATION:

Students will be collecting, counting, and classifying macroinvertebrates during their park visit. It is essential that students be familiar with the macroinvertebrates they may find in the park stream, how to identify them, and their relative sensitivities to pollution. The more students know about the macroinvertebrates before the field study, the more comfortable they will be finding the organisms, resulting in better data collection, and a more enjoyable and rewarding experience.

Identification of macroinvertebrates is a skill that takes time and practice to develop. This activity, either online or in class with a PowerPoint, will familiarize students with many organisms and how to classify them. Successful identification relies on the skill to quickly observe the most dominant physical features of organisms.

IMPORTANCE OF OBSERVATION

Observation is a vital skill and very important for macroinvertebrate identification. Many of the macroinvertebrates are quite small. Although visible to the unaided eye, one needs to develop a discriminating eye to pick out key features.

Another obvious reason for careful observation is the simple fact that these organisms are living and therefore actively moving. Encourage the students to look for generalized, broader characteristics. Time is of the essence and is limited in the PowerPoint ID activity.

PROCEDURE: FOR POWERPOINT:

1. Visit the Alice Ferguson Foundation Youtube page. Present students "Activity: Is Your Stream Clean?" video to introduce identifying macroinvertebrates or copy this link: https://youtu.be/EFdWF80rR2o?

2. Hand out Macroinvertebrate Identification worksheet. Present the Macroinvertebrate Identification PowerPoint from the Alice Ferguson Foundation website's Resource Library, along with the worksheet, under "Water Canaries: Macro ID"

Goals:

- To learn how to identify macroinvertebrates.

Class Time:

One Class Period

Group Size:

The PowerPoint presentation is a whole group activity in which you lead students through.

Students can work on the online interactive lesson either individually at home or in groups of two in class if students have computer access.

Materials:

- Alice Ferguson Foundation Website's Resource Library
- Alice Ferguson Foundation's Youtube channel
- Macroinvertebrate ID PowerPoint
- Macroinvertebrate ID worksheet for each student
- Macroinvertebrate ID Interactive Lesson/Game
- Computer access
- Pencils

Macroinvertebrate Identification

EXPLORATION

PROCEDURE continued

3. Have the students observe the slide "Macroinvertebrate Identification Worksheet." Explain that they will have only 2 minutes to observe and make quick notes and/or sketches to use later on in identifying 15 unknown benthic macroinvertebrates. During the first practice slide, students should focus their observations on a few physical characteristics of benthic macroinvertebrates: body shape, legs, tails, and gills.

SPECIAL NOTE:

Students often jump to the end of the key to look for an organism by its picture. This leads to errors in identification due to similarities between organisms.

WHAT TO OBSERVE:

4. On the practice slide, direct the students' attention to the key characteristics listed on the worksheet (body shape, legs, tails, gills, and other noticeable features). Remind students that they should focus on creating sketches that are rough graphical reminders of body shape, legs, tails, gills, or other features, not on drawing perfect works of art.

   Some slides have more than one picture of a type of macroinvertebrate. Students should focus on only one picture, but you should inform them that there are variations within the same animal species.

IDENTIFICATION PROCESS:

5. Start the PowerPoint, which will automatically shift to the next slide after two minutes.

6. Once the class has progressed through the slides and recorded observations, hand out the dichotomous key and help them identify each numbered organism using a dichotomous key. Identify the practice slide organism as a class to review the process. The key can be found from Alice Ferguson Foundation website's Resource Library, under "Macroinvertebrate Key." This is the same key students will use during their field study.

EXTENSION/HOMEWORK

1. As a student-led addition, students can do an interactive Macro-Invertebrate Identification activity found on the Alice Ferguson Resource Library or through this link: fergusonfoundation.org/resources/game-macro-invertebrate-identification/

2. Complete the activity. Students should complete Macroinvertebrate ID for both Lazy Branch and Scrubby Creek. After identifying all six animals, students will be asked to determine which stream is the healthiest.

Macroinvertebrate Identification

EXPLORATION

MACROINVERTEBRATE IDENTIFICATION CHART

Characteristics			Drawing
Ex.	Body Shape		
	Legs		
	Tail		
	Other		

Characteristics			Drawing
Ex.	Body Shape		
	Legs		
	Tail		
	Other		

Characteristics			Drawing
Ex.	Body Shape		
	Legs		
	Tail		
	Other		

Make-A-Macro

EXPLORATION

BACKGROUND INFORMATION

What is an Adaptation?

Adaptations are characteristics that are outcomes of natural selection, and increase chances of survival and reproduction. Adaptations can be physiological (body parts), behavioral (actions that increase survival), or structural (other physical features that aid survival).

Example of an Adaptation:

Benthic macroinvertebrates have an array of structural adaptations that aid in their survival. Black fly larvae, for instance, have little feather brushes on their heads that help them collect food. Whirligig beetles have eyes divided horizontally so they can see both on top of and below the water line. The water boatman paddles underwater with long, oar-like legs, covered in hairy fringe, which spread out on the forward stroke and fold in on the return. This allows it to get the most power out of the forward stroke and reduce drag on the recovery.

Benthic macroinvertebrates have a range of behavioral adaptations critical to their survival as well. When water gets too warm and oxygen levels decrease, stoneflies will do "push-ups" to increase the amount of water flowing over their gills to increase oxygen. The net-building caddisfly larva attaches a funnel-shaped net to a rock, and then periodically creeps out of its crevice to harvest the tiny plants and animals caught in the mesh.

Human Adaptation:

What physical characteristics do humans have to survive and reproduce? The human body readily responds to changing environmental stresses in a variety of biological and cultural ways. We can acclimatize to a wide range of temperature and humidity. When traveling to high altitudes, the level of oxygen is the same, but at a couple of miles above sea level, the pressure is lower, so the oxygen molecules are farther apart. Over time, our bodies adjust to the lower pressure and adapt to a less dense atmosphere. We also are constantly responding in physiological ways to internal and external stresses such as bacterial and viral infections, pollution, and dietary imbalances. To understand structural adaptations, try to zip a zipper without using your thumbs.

PROCEDURE: MAKE-A-MACRO STEP-BY-STEP

1. **PREPARATION: Create Cards**
   a. Copy the body part card masters onto cardstock, one set for each group of students.

Goal:

To apply understanding of macroinvertebrate adaptations to design the ultimate macroinvertebrate.

Class Time:

One class period; two class periods for students needing more background instruction time

Group Size:

3-4 students per group

Materials List:

- 1 set of macroinvertebrate adaptation cards per group
- Scissors for cutting out the macroinvertebrate body parts
- Glue
- Copies of assessment rubric (one per group)
- Flip chart, chalkboard, or whiteboard for recording definitions/answers
- Choice of crayons/colored pencils/markers/paint

Make-A-Macro

EXPLORATION

b. Cut the cards apart. Have them create a new macroinvertebrate from the cards. Based on what they learned in the macroinvertebrate PowerPoint or online activity, have them describe the conditions under which their macroinvertebrate will thrive.

2. PRESENTATIONS
   a. Each group will present its macroinvertebrate to the class.
   b. Each group should identify and explain its macro, including its name, what adaptations are present, how it has adapted to its environment, and what adaptations are important to its survival.
3. EXTENSION/HOMEWORK
   a. Ask students to research the life history of a specific macroinvertebrate of their choice. Many of them are juvenile forms of insects.
   b. How are they adapted for where they live and what they eat? How would a sudden change in temperature and habitat affect them?
   c. Investigate how some macroinvertebrates got their names. For example, why is a dragonfly larvae called a "dragon" fly? Explore the scientific names of various macroinvertebrates.
   d. Students can answer these questions by writing a report or making an inforgraphic

SUGGESTED ADAPTATIONS:

- Have more physically active students pantomime and verbally explain the adaptations of their invented macroinvertebrate instead of drawing and writing.

  For students who need extra instruction split this into two class periods. Students can create their own macroinvertebrate in the first period and then describe its adaptations during the second class period.

- If students are having difficulty grasping the concept of adaptations, show them pictures of animals which have obvious adaptations:

  Giraffe → long neck → allows it to eat leaves from tall trees

  Zebra → stripes → camouflages in tall grasses

  Owl → large eyes → helps it to see prey at night

Make-A-Macro

EXPLORATION

Group Members/Name: ______________________________

Date: ______________

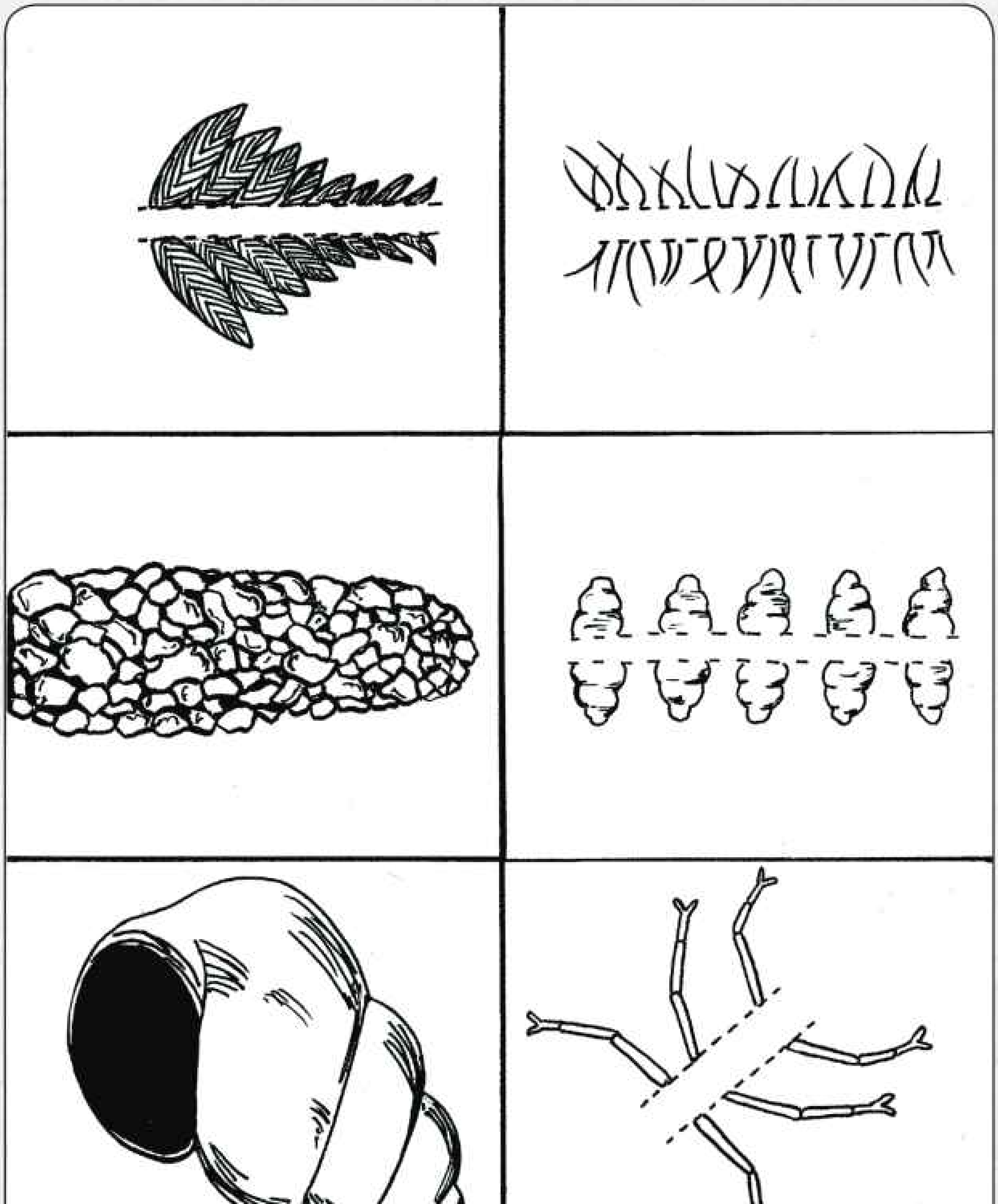
Your group is to create an original, fictitious macroinvertebrate that has all of the body parts on the cards you randomly selected. You'll need to select parts to complete your macro, and then provide an explanation that includes where your macro lives, what it needs in its habitat to survive, and how its various body parts help it to compete. Your group will be assessed based upon the criteria in the following rubric.

RUBRIC FOR MAKE-A-MACRO

CRITERIA	3	2	1	0
Adaptations are present and explained in picture.	All adaptations and explanations are present in picture.	Missing one or two adaptations and/ or explanations in picture.	Missing more than 2 adaptations and/ or explanations in picture.	Adaptations and/ or explanations are absent in picture.
Name of macroinvertebrate and reasoning for name.	Name and reasoning for name are present and well-explained.	Name and reasoning for a name is present but not well-explained.	Just name is present; reasoning for name is absent.	Name and reasoning for name are absent.
How has the macroinvertebrate adapted to the environment?	Description for adaptation is detailed and supported with reason.	Description for adaptation is fair and somewhat supported.	Description for adaptation is weak and not well-supported.	Description for adaptation to environment is absent.
How are the adaptations important to their survival?	Importance of adaptation is detailed and supported with reason.	Importance of adaptation is fair and somewhat supported.	Importance of adaptation is weak and not well-supported.	Importance of adaptation is absent.

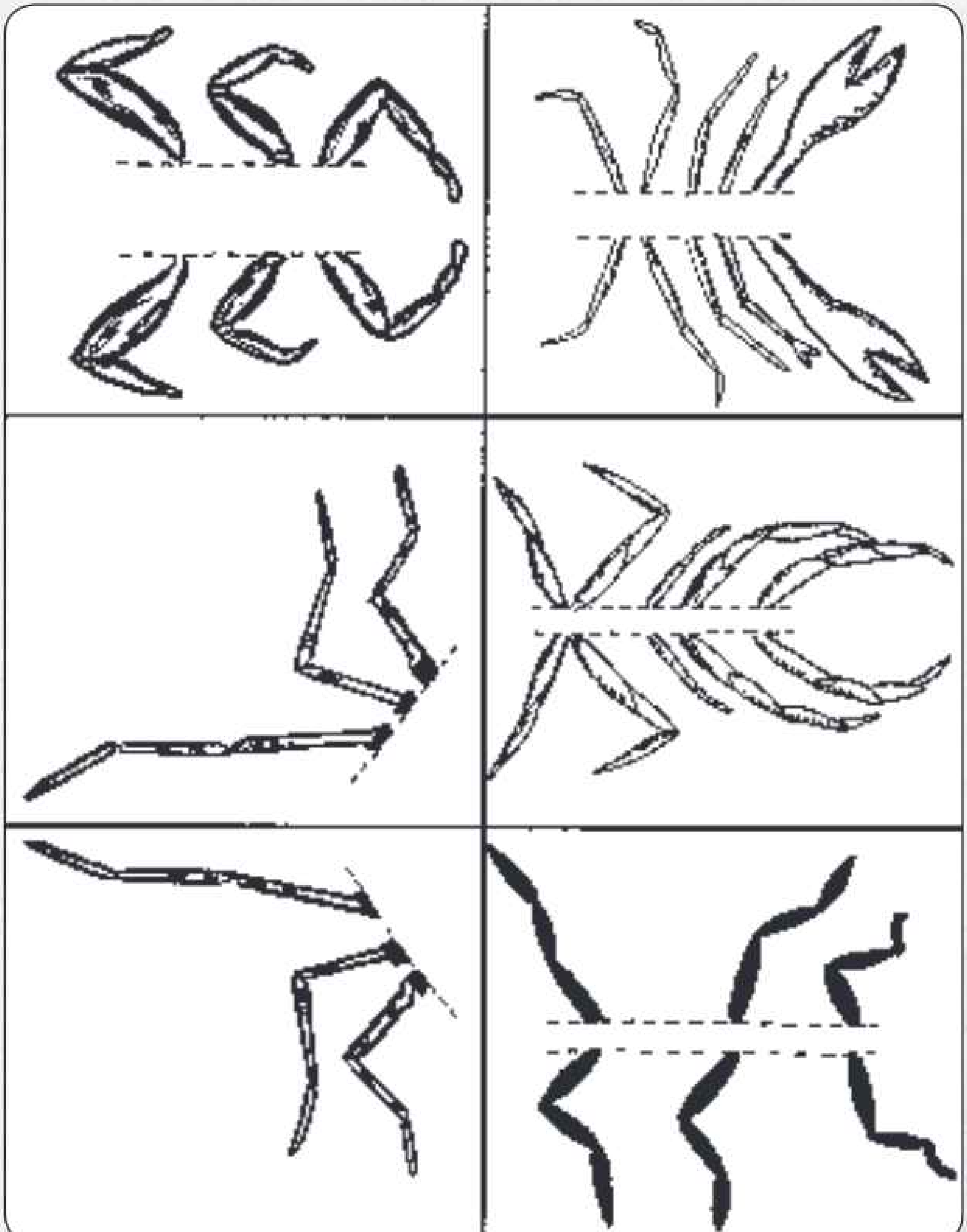
Make-A-Macro

EXPLORATION



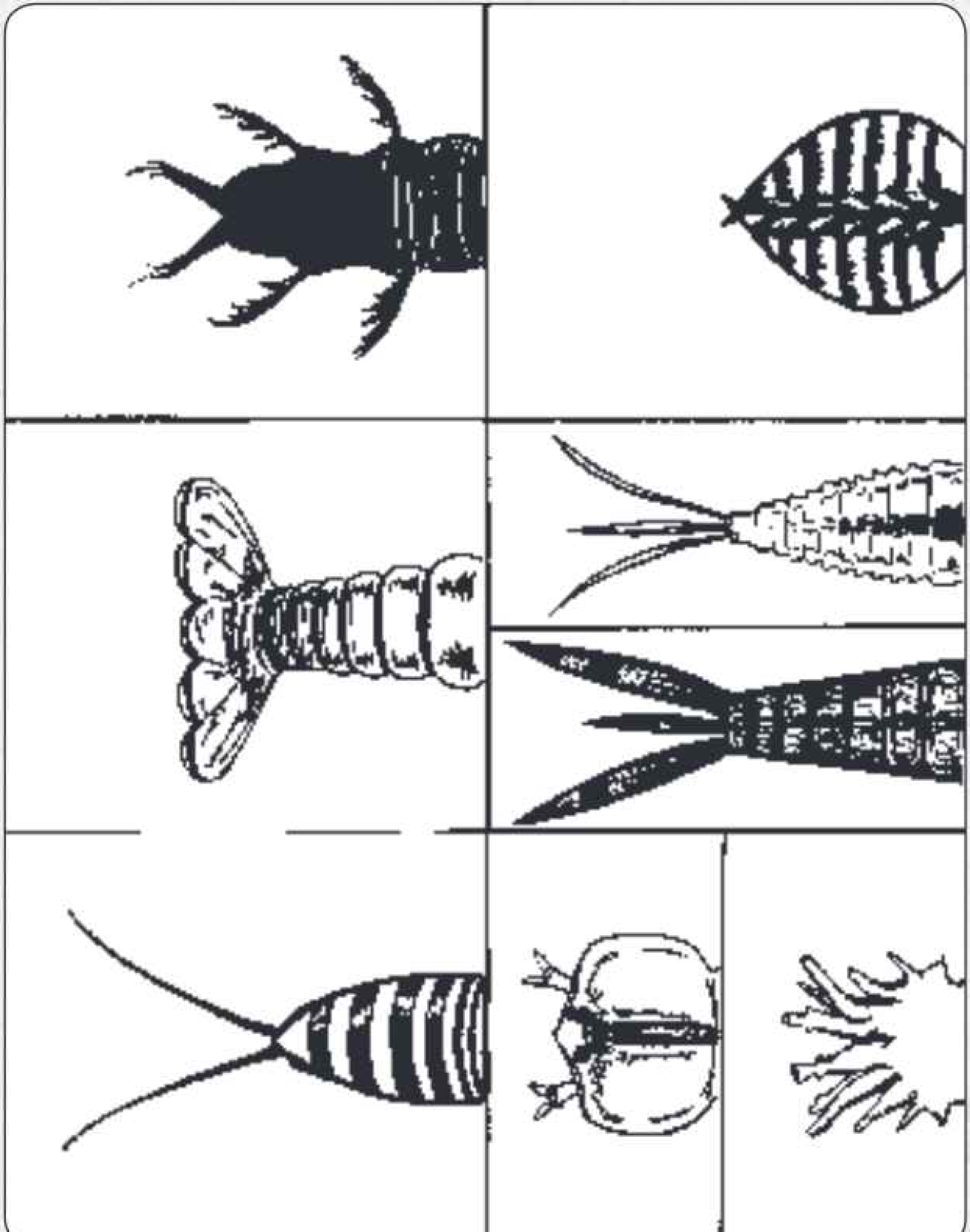
Make-A-Macro

EXPLORATION



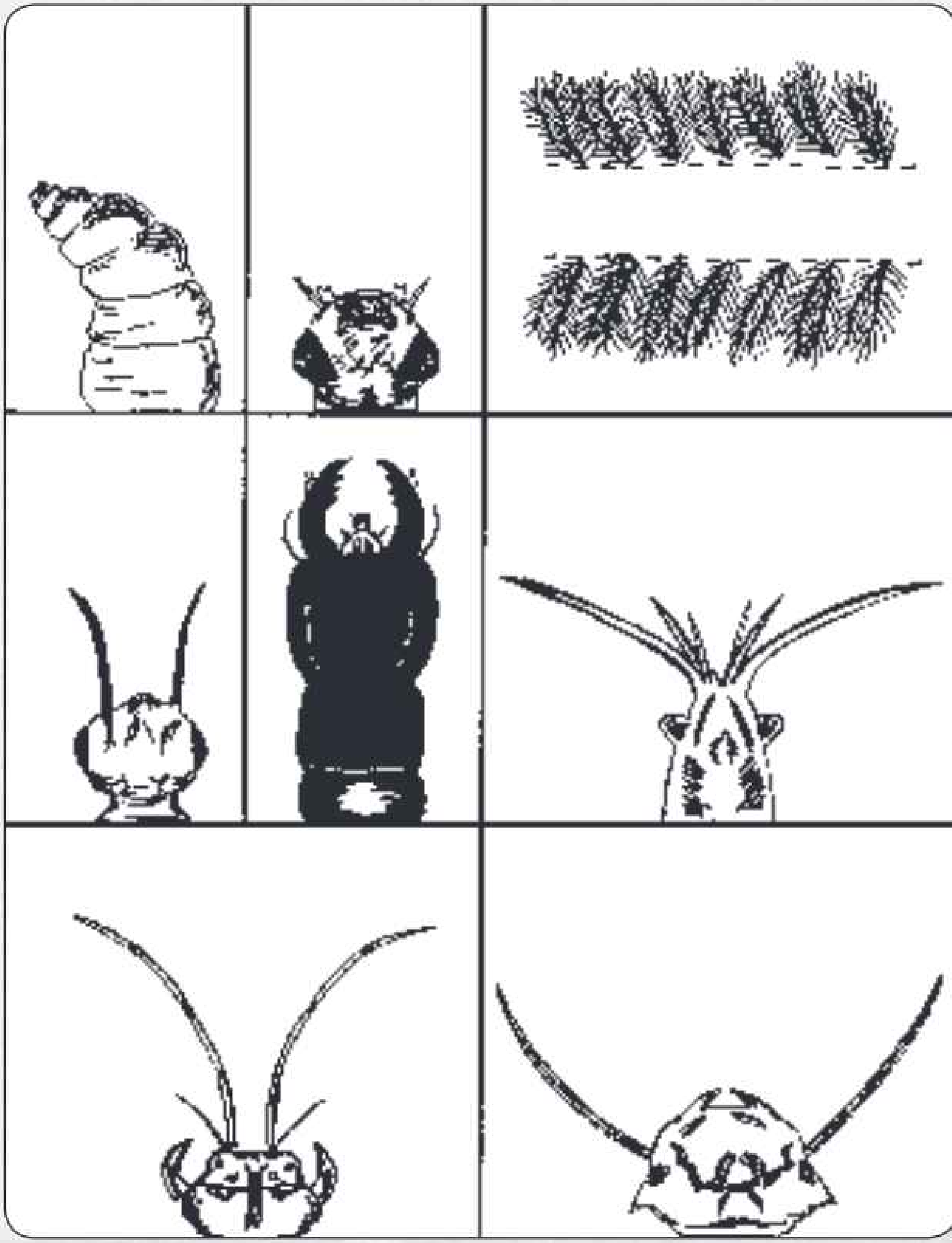
Make-A-Macro

EXPLORATION



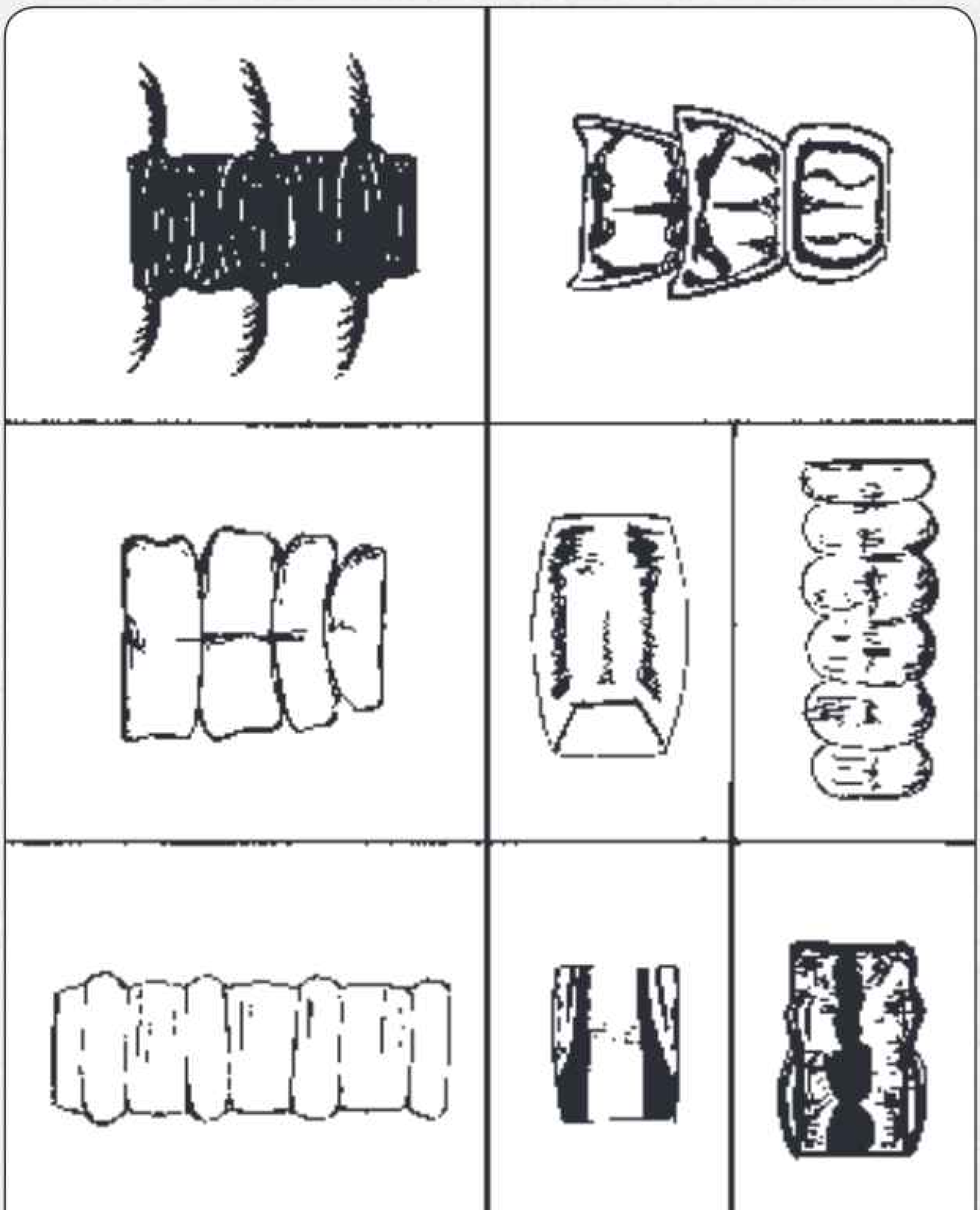
Make-A-Macro

EXPLORATION



Make-A-Macro

EXPLORATION



Plan Wisely for Your Students' Field Study

ENGAGEMENT

BACKGROUND INFORMATION:

It is crucial that all students be prepared for the field study in the park. For many students, working outdoors will be an unusual and challenging experience. You should review the information in this section carefully with your students to help them prepare mentally for the field study, and to ensure that they have the appropriate dress and supplies to be comfortable in the park. You may have to review this information several times before the park field study to be sure all students understand the required preparations and plan well for their visit. Listening to the weather and developing a what-to-wear list for the day is a great homework assignment or class discussion in advance of the field study. Some teachers do a dry run a few days in advance of the field study by having their students come to school wearing their field study clothes with their backpacks packed as if for the field study.

Before the site visit, review the Data Sheet in the Student Pages to ensure your students understand what data they will be required to obtain. Pay particular attention to the questions each group must answer in addition to the data they collect. Students can read the resource information to learn about the observations they will be required to make in the park.

The Alice Ferguson Foundation educator and National Park ranger will have all the supplies for the field study activities.

PARK INFORMATION:

Students can review information about the park and its history on the Bridging the Watershed website at fergusonfoundation.org or by visiting the National Park Service website at nps.gov.

THINGS TO BRING:

- There won't be a place to buy food. Students must bring a trash-free lunch and a reusable water bottle. For students on a school lunch plan, let the cafeteria manager know about the field trip a few days in advance to ensure that a bagged lunch will be available.
- The hotter the weather, the more students should bring to drink. Have students pack their lunch and drinks in a backpack or bag that they can easily carry into and out of the park study site.
- Keeping in the ecology-minded spirit, suggest that students make their lunch as trash free as possible. Some areas and parks do not have trash cans. What is packed in must be packed out.
- Make sure that students bring sunscreen and insect repellent if desired.

Goal:

To help students plan and prepare for their field study in a local national park.

Plan Wisely for Your Students' Field Study

ENGAGEMENT

PARK STEWARDSHIP:

- Remind students that collecting of any type is not permitted.
- Remind students to take only photographs and leave only footprints.

TIPS ABOUT CLOTHING:

- Students should wear comfortable clothing that allows them to easily move, hike, bend, and climb. Students may have to gather data in a wet and muddy environment, so they should choose clothes they don't mind getting wet and dirty. With the Water Canaries module, some students will be going into the water to collect organisms. We suggest that students bring an extra pair of socks in their backpacks.
- Dress for the weather. In cool weather, encourage students to wear layers of clothing to keep them warm in the early morning, but that they can remove later in the day or while working. If the forecast calls for possible rain, students should wear a waterproof jacket, hat, and shoes, and bring a plastic bag for materials.
- Even in warm or hot weather, encourage students to wear long pants and a long-sleeved shirt for protection from poison ivy and briars. Students may be in a wooded area or may walk through tall grass.
- The datasheets your students will use on their field study are included here so they can be well-prepared for what the will be asked to do in the park. You will not need to bring these with you. Your AFF educator will have all the materials you will need for your field study.

Plan Wisely for Your Students' Field Study

ENGAGEMENT

Bridging the Watershed
Water Canaries Datasheet

Date: ______

Teacher: ______

Park: ______ Study Site: ______

Park Rangers & Educators: (one per row) | Group Members: (one per row)

Latitude: North ______ ° Longitude: West ______ °

Why is it important to know the latitude and longitude?

	Yesterday			Today		
Air Temperature	°C			°C		
Cloud Cover	☐ Clear	☐ Partly Cloudy	☐ Cloudy	☐ Clear	☐ Partly Cloudy	☐ Cloudy
Precipitation	☐ None	☐ Rain	☐ Other	☐ None	☐ Rain	☐ Other

How could weather affect today's field study?

Water Color ______ Water Odor ______ Water Temperature ______ °C

Stream Bottom: ☐ Rocky ☐ Sandy/Gravel ☐ Silty

Stream Canopy: ☐ Full Shade ☐ Partial Shade ☐ Sun

How are water temperature, stream bottom, and canopy related?

Stream Speed:

Trial 1 ______ Seconds

Trial 2 ______ Seconds

Trial 3 ______ Seconds

Average ______ Seconds (Add all 3 Trials and divide by 3)

Stream Speed measured with digital probe: ______ ft/s

Use the average time from above in the calculation below to determine average stream speed

10m / ____ [average time]= ______ meters/second

Because we test speed only at the surface of the stream, we use a 'fudge factor' of 0.8 to adjust for an overall stream speed. Use the average speed from above to find the overall stream speed:

Average Speed x 0.8 (fudge factor) = ______ meters/second

Plan Wisely for Your Students' Field Study

ENGAGEMENT

Sketch the study site, showing all details that affect your field study:

Macroinvertebrate Collection (Write in numbers only)

Alderfly, Fishfly, Hellgrammite	
Aquatic Sowbug	
Aquatic Worms	
Beetle & Water Penny	
Blackfly	
Clam	
Cranefly (Truefly)	
Crayfish	
Common Netspinner Caddisfly	
Damselfly & Dragonfly	

Flatworm	
Gilled Snail	
Leech	
Lunged Snail	
Mayfly	
Midge	
Most Caddisflies	
Scud	
Stonefly	

Other/Notes:

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Macroinvertebrates: Collect, Classify and Count

EXPLORATION

BACKGROUND INFORMATION:

Benthic macroinvertebrates (organisms that live in or on the bottom of a water body) vary in their sensitivity to stress in their habitat. Students will collect, classify, and count macroinvertebrates to help determine the health of a stream. Because stream benthic macroinvertebrates are classified into categories according to their tolerance to pollution, the relative number of each species gives an indication of the environmental stress the stream is under. Your AFF educator will direct park activities with assistance from the classroom teacher when appropriate.

Goal:

To assess water quality by collecting, classifying and counting macroinvertebrates found in a stream.

Class Time:

This field study will be completed in a single, minimum 3-5 hour visit to a national park.

Group Size:

3 to 4 students

Materials List:

Your AFF educator will have everything your students will need for their field study.

Data Analysis – Determine Stream Health Using Macroinvertebrate Counts

PROCEDURE:

1. Refer to the Macroinvertebrate Survey Data Sheet. Determine the number collected for each species and record in the "Number Collected" column in Table V: Total Index Value for Stream.

2. Enter "Number Collected" for each species in the block(s) under the headings "Sub-Categories A-F" to the right of the species name. Because of the pollution tolerance level of each category of species used in computing the water quality, you will need to copy the "Number Collected" two or three times for certain species.

3. Total the numbers in all columns and write the totals in line 3.

4. Compute the percentage of the total number of organisms for each column and write in line 4.

5. Use the percentages computed in step 4 to determine an index value for each sub-category. Consult Table IV: Index Values assigned to Sub-Categories. Determine an index value of 2, 1, or 0 by finding where the percentage of each sub-category best fits. Record index values in line 5.

6. Add all index values to obtain a total index value for the stream and write the value in line 6.

7. Mark an "X" on the scale below Table V, corresponding to your total index value, to determine your stream's health.

TABLE IV: INDEX VALUES (%)

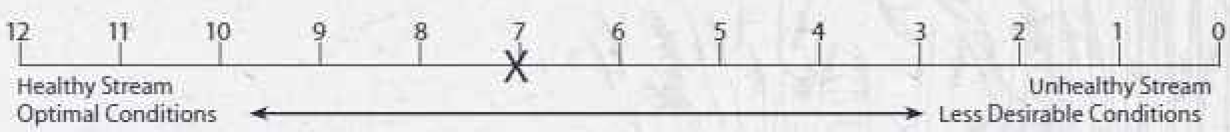
Sub-Categories	2	1	0
A	> 32.2	16.1 – 32.2	< 16.1
B	> 6.4	3.2 – 6.4	< 3.2
C	< 19.7	19.7 – 34.5	> 34.5
D	< 0.3	0.3 – 1.5	> 1.5
E	< 46.7	46.7 – 61.5	> 61.5
F	< 5.4	5.4 – 20.8	> 20.8

> greater than
< less than

Data Analysis – Determine Stream Health Using Macroinvertebrate Counts

TABLE V: TOTAL INDEX VALUE FOR STREAM

	Species	1. Number Collected	2. Sub-Categories					
			A	B	C	D	E	F
Sensitive	Mayfly larvae	12	12					
	Stone Fly larvae	8	8					
	Most Caddisfly larvae	3	3					
	Beetles (adults & larvae)	2		2				
Somewhat Sensitive	Dragonfly larvae Damselfly larvae	11					11	
	Common Netspinner larvae	3			3			
	Crayfish	5						5
	Gilled Snails	0						0
	Aquatic Sowbugs	0					0	0
	Scuds	2					2	2
	Clams	0					0	0
	True Fly larvae	6						
	Hellgramites, Fishfly larvae, Alderfly larvae	4						
Tolerant	Lunged Snails	1				1	1	1
	Black Fly larvae	2					2	
	Midge larvae	15					15	
	Aquatic worms	1					1	1
	Flatworms	0					0	0
	Leeches	0					0	0
3. Sum of numbers in each column		75	23	2	3	1	32	9
4. Percentage of total number of macroinvertebrates in each sub-category		100%	31%	3%	4%	1%	43%	12%
5. Index value for each sub-category			1	0	2	1	2	1
6. Total index value for stream								7

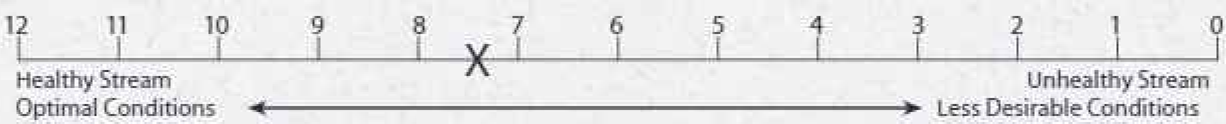


Data Analysis – Determine Stream Health Using Macroinvertebrate Counts

TABLE VI: CLASS TOTAL INDEX VALUE FOR STREAM

Sub-Category	Class Groups					Class Average
	1	2	3	4	5	
A	1	1				1.0
B	0	1				.5
C	2	1				1.5
D	1	2				1.5
E	2	1				1.5
F	1	2				1.5
			Total index value for stream			7.5

Hint: Class total index value for stream is the sum of class averages.



Performance List

ELABORATION

Group Members ______________________ Date __________

Performance Criteria	Assessment		
	Points	Group	Teacher
1 All group data are entered, and an average total index value for the group is accurately determined.			
2 All class data are entered, and an average total index value for the class is accurately determined.			
3 The summary report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data and total index value, a descriptive assessment of the health of the stream is included.			
5 Individual water quality parameters that exceeded significant levels are noted, and possible reasons are proposed.			
6 The summary is clear and concise, and accurately reflects the findings of the study.			
7 Scientific terminology and concepts are accurately explained and applied to illustrate major points of the report.			
8 Visual aids (photographs, charts, graphs, and drawings, etc.) enhance understanding of the text.			
9 Visuals are clearly titled, labeled, and referenced within the text.			
10 Language used in the report is purposeful, descriptive, and appropriate for the intended audience.			
Total			

Teacher Comments:

Potomac Confidential

ELABORATION

BACKGROUND INFORMATION:

"Potomac Confidential" is a graphic novel that introduces students to the topic of benthic macroinvertebrates (see Resources section for complete description). The characters represent different organisms in a stream's benthic environment. Some are tolerant of environmental disruptions, including changes in dissolved oxygen levels and nutrients, while others are more sensitive. The graphic novel also describes physical characteristics of some of the benthic organisms, giving students a foundation from which they will begin to learn identification techniques.

Instruct students to read Potomac Confidential, or lead a group reading of the graphic novel (to help this, include a list of characters with speaking parts).

DISCUSSION QUESTIONS:

1. What happened to the stream to make conditions unfavorable for the macroinvertebrates?
2. What do you think we'd find if we sampled for macroinvertebrates in both streams?

   Many teachers like to re-read "Potomac Confidential" later in their unit so students can re-check their understanding of the material.

POTOMAC CONFIDENTIAL:
The Case Of The Missing Macroinvertebrates

Authors:
Katrina Fauss, BTW educator
Rebecca Fordham, BTW educator
Will Sheppard, BTW educator
Anna Wadhams, BTW educator

Graphic Designer: Emily Wright
Artist: Jessica Miller

Goal:

To understand how the presence of certain organisms can give us information about the health of the environment.

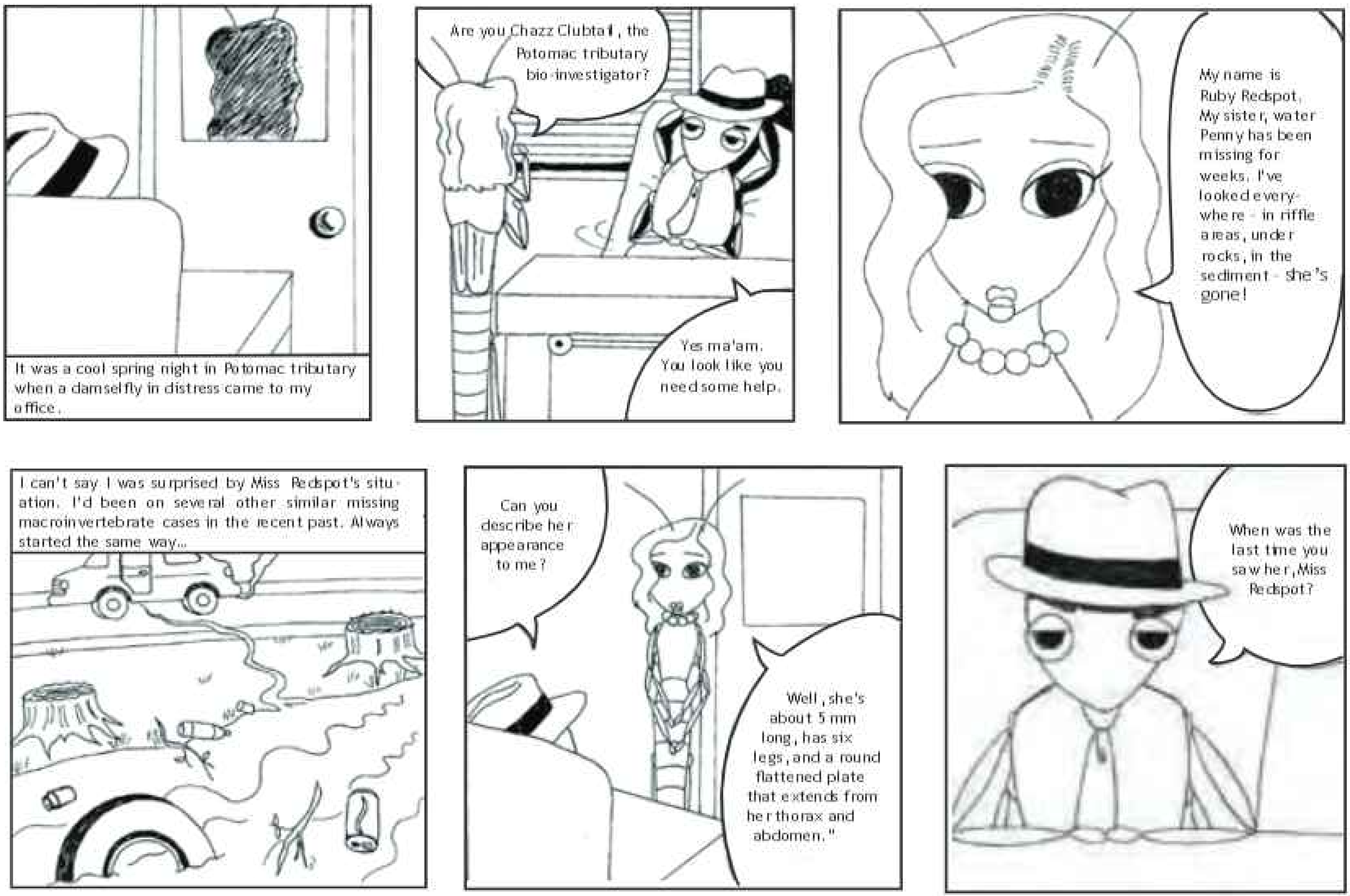
Class time:

One class period

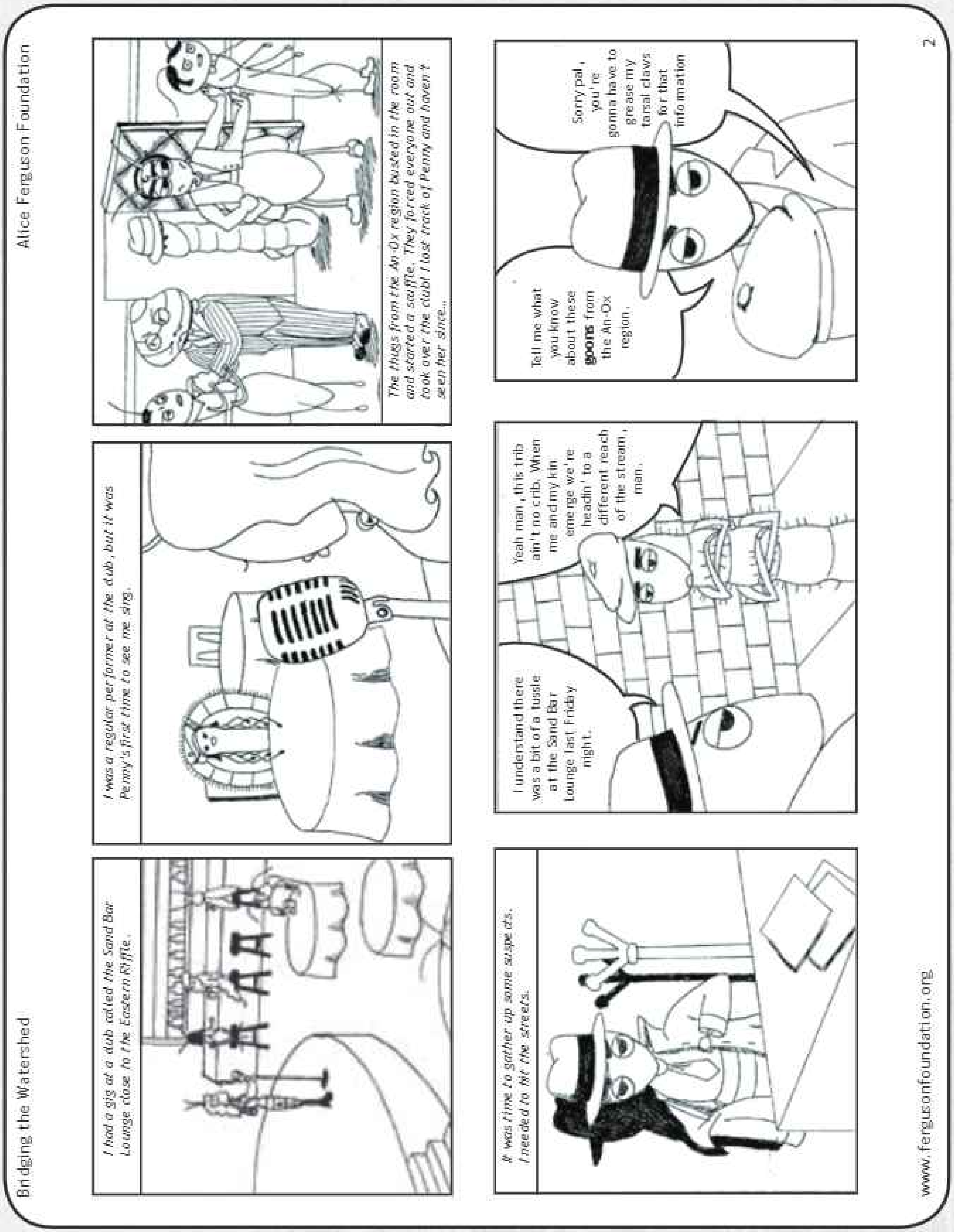
Group Size:

No groups. Provide each student with a copy of the graphic novel.

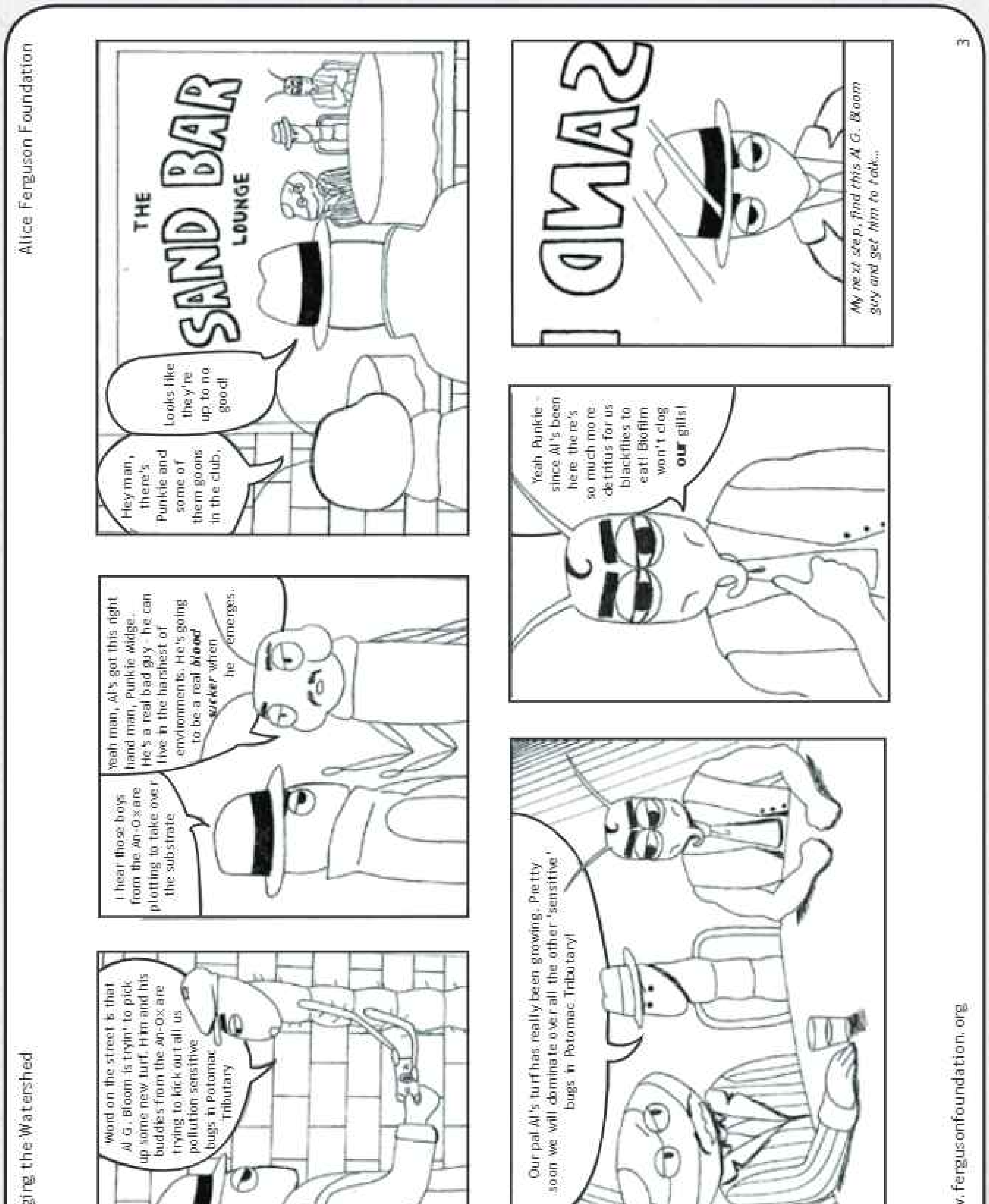
Potomac Confidential



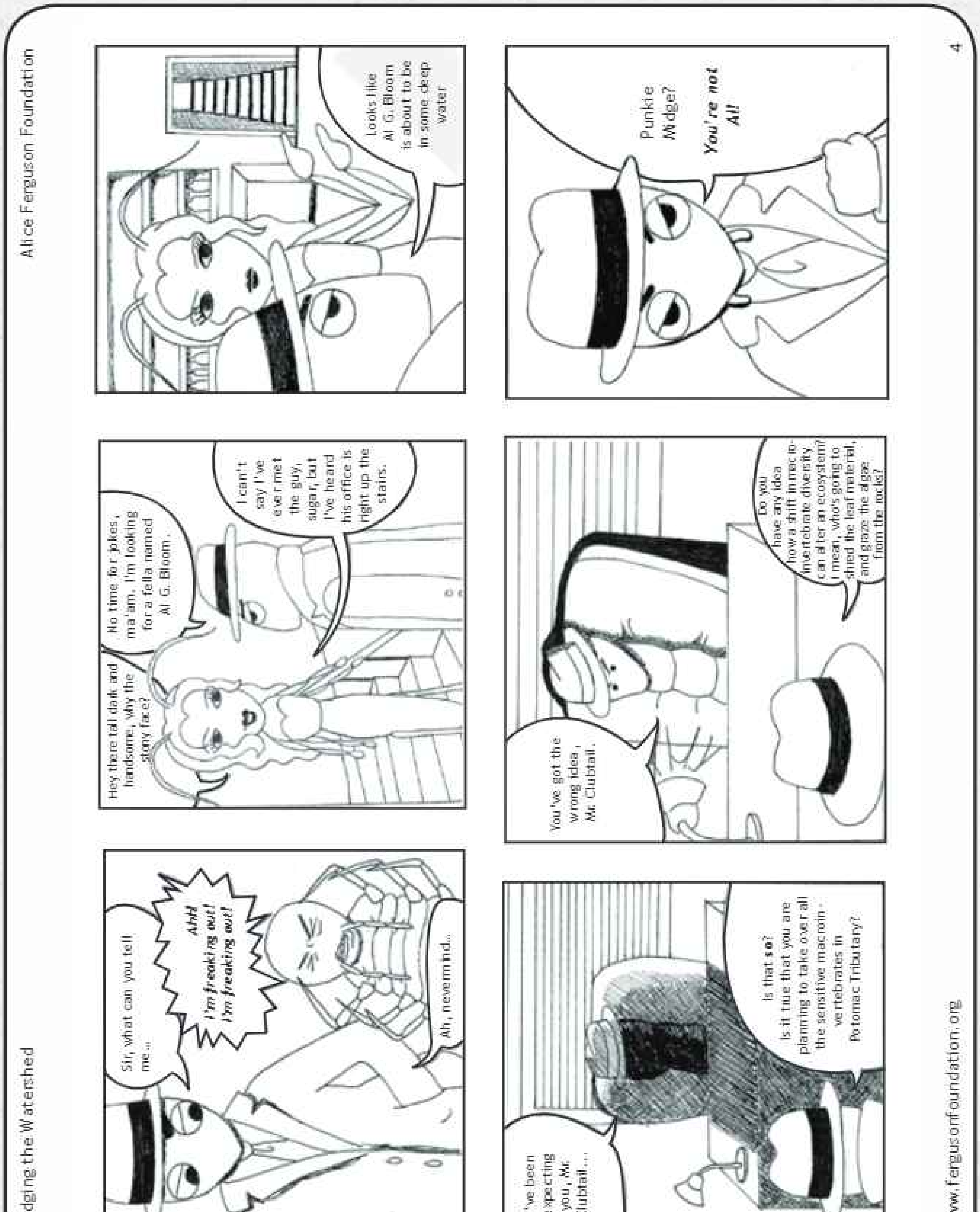
Potomac Confidential



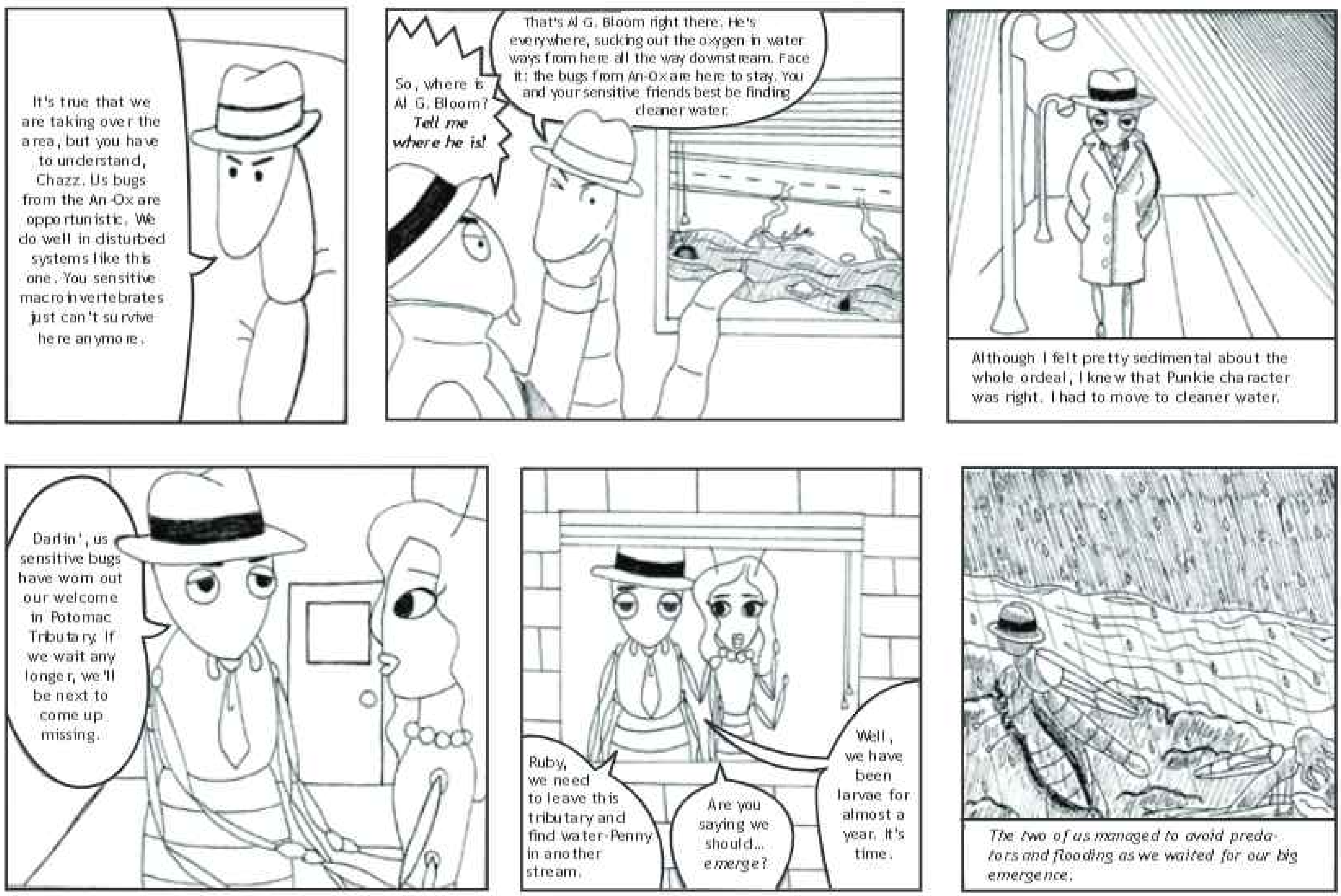
Potomac Confidential

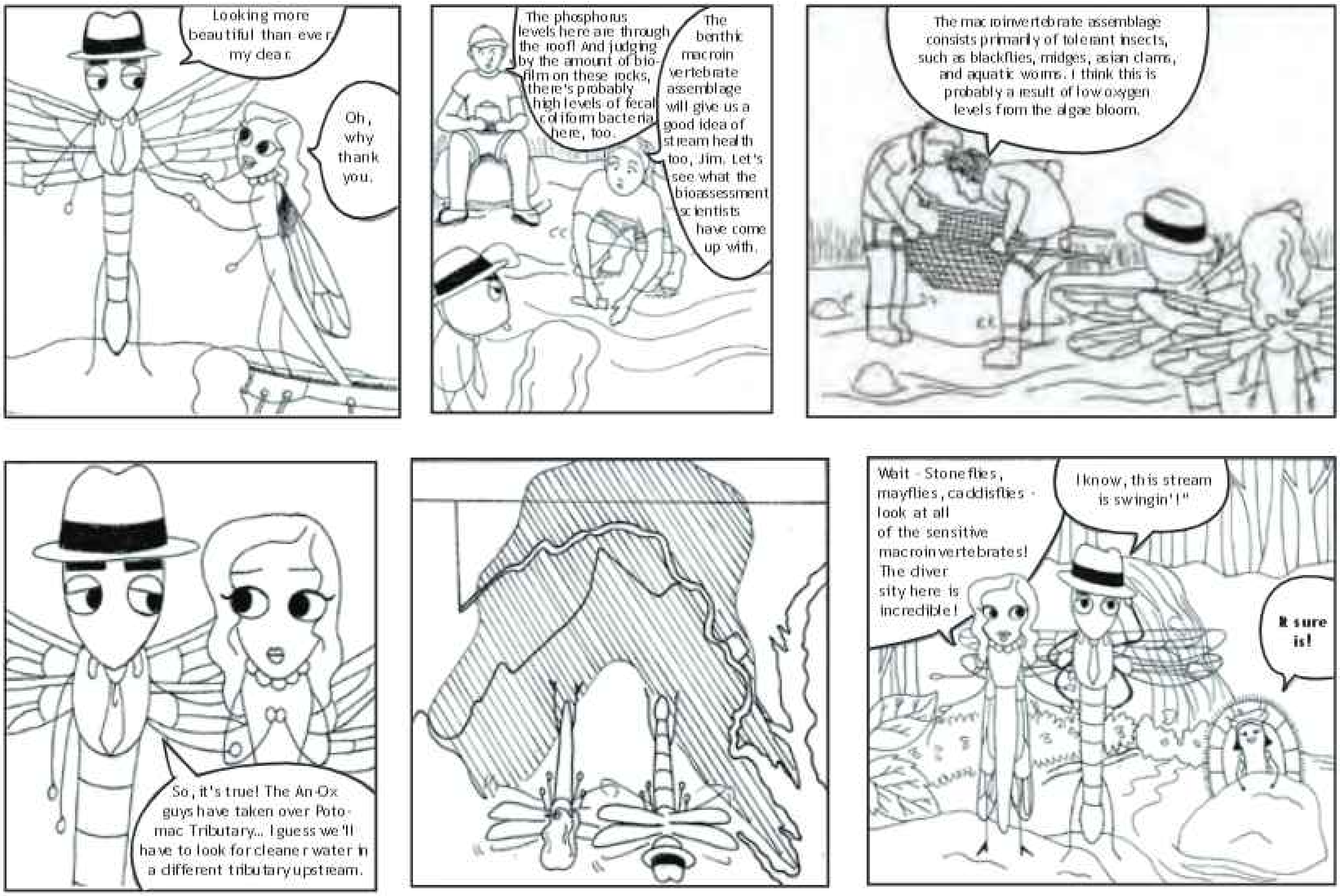


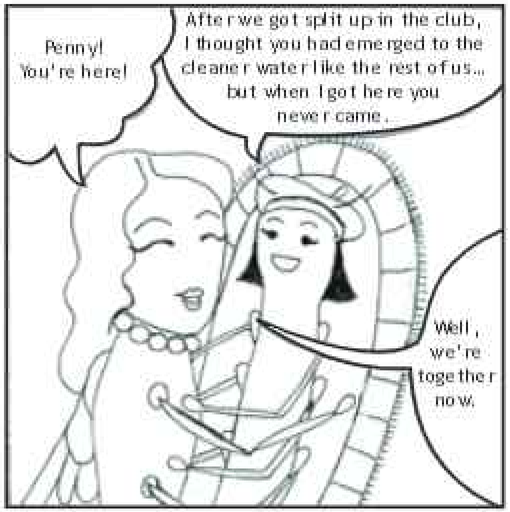
Potomac Confidential

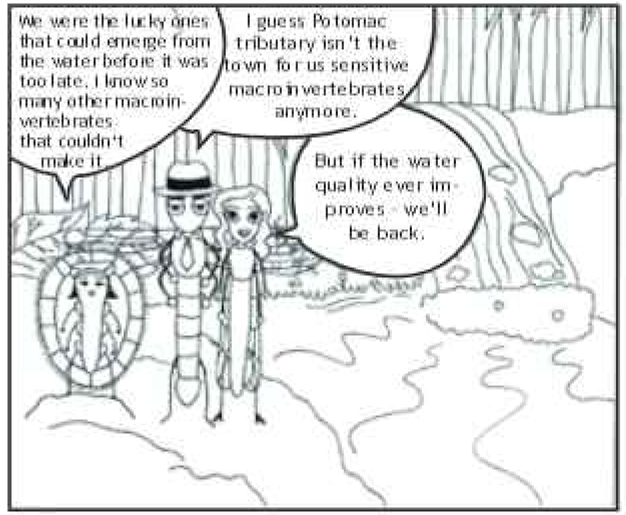


Potomac Confidential




Looking more beautiful than ever, my dear.
Oh, why thank you.
The phosphorus levels here are through the roof! And judging by the amount of bio-film on these rocks, there's probably high levels of fecal coliform bacteria here, too.
The benthic macroinvertebrate assemblage will give us a good idea of stream health too, Jim. Let's see what the bioassessment scientists have come up with.
The macroinvertebrate assemblage consists primarily of tolerant insects, such as blackflies, midges, asian clams, and aquatic worms. I think this is probably a result of low oxygen levels from the algae bloom.
So, it's true! The An-Ox guys have taken over Potomac Tributary... I guess we'll have to look for cleaner water in a different tributary upstream.
Wait - Stoneflies, mayflies, caddisflies - look at all of the sensitive macroinvertebrates! The diversity here is incredible!
I know, this stream is swingin'!"
It sure is!


Penny! You're here!
After we got split up in the club, I thought you had emerged to the cleaner water like the rest of us... but when I got here you never came.
Well, we're together now.


We were the lucky ones that could emerge from the water before it was too late. I know so many other macroin-vertebrates that couldn't make it.
I guess Potomac tributary isn't the town for us sensitive macroinvertebrates anymore.
But if the water quality ever improves - we'll be back.

Now You See Them; Now You Don't

ELABORATION

BACKGROUND INFORMATION:

Students have examined the macroinvertebrate population of a stream that is part of the Potomac River watershed. The stream they sampled will eventually drain into the Chesapeake Bay, along with any pollution it contains. The health of that stream will ultimately affect the health of the Bay. In this activity, students will complete a data table and analyze a graph from macroinvertebrate sampling in the Potomac River watershed using the following scenario:

There has been a major chemical spill from a coal plant located near the headwaters of the Potomac River in West Virginia. You will be sampling three downstream sites to determine the short-term effects of the spill on the benthic macroinvertebrate population. Before you go out in the field, you want to study the surrounding land cover and land-use types to make hypotheses about how each stream site will be affected.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. Look at a map of the Potomac River Watershed. **Find and label the Potomac River.**
2. **Macroinvertebrates in the Potomac River tributaries are monitored on a continuing basis. Refer to Table VII: Macroinvertebrate Species Count - Potomac River. The data was compiled from three different tributaries along the Potomac River in one year.**
3. **For each of the three sites calculate the percent of total number and determine the index value for each sub-category. Add all sub-categories at each site to determine the total index value.**
4. **Place an "X" on the scale below Table VII marked 0 to 12 to get an idea of stream health at each site.**
5. **At the time of the sampling, one of the sites was under environmental stress from wastewater runoff. Which site do you think it was? Use the data from the three sites to support your answer.**

   Site 3 – Total Index Value is low. Even though there is a higher total number of organisms, there are more species of organisms that are pollution tolerant and fewer species that are sensitive or somewhat sensitive.

Goals:

- To assess the health of three sites on the Potomac River.
- To relate macroinvertebrate populations to the degradation of benthic habitat in the Potomac River watershed.

Class Time:

45 minutes

Group Size:

2–4 students

Materials:

- Worksheets in Student Pages

Special Considerations:

- Some familiarity with geographic information systems is helpful. Show students a map of the Potomac River Watershed.

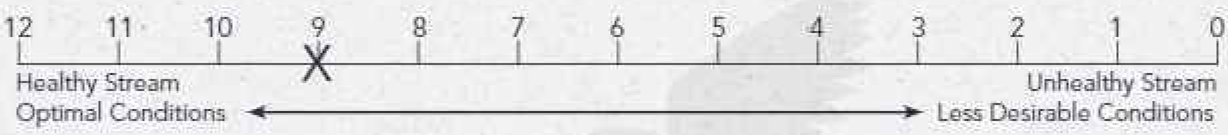
Now You See Them; Now You Don't

ELABORATION

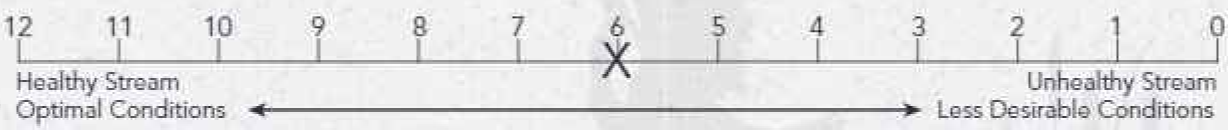
TABLE VII: MACROINVERTEBRATES SPECIES COUNT — POTOMAC RIVER

	Site 1			Site 2			Site 3		
Sub-Category	Number Collected	Percent of Total Number	Index Value	Number Collected	Percent of Total Number	Index Value	Number Collected	Percent of Total Number	Index Value
A	39	37.5	2	30	28	1	2	1	0
B	9	8.6	2	4	3.7	1	1	.49	0
C	26	25	1	6	5.6	2	5	2.5	2
D	1	0.96	1	7	6.5	0	7	3.5	0
E	15	14.4	2	27	25.2	2	88	43.7	0
F	14	13.5	1	33	30.8	0	98	48.7	0
Total (all sub-categories)	104	100%		107	100%		201	100%	
	Total Index Value for Site 1		9	Total Index Value for Site 2		6	Total Index Value for Site 3		2

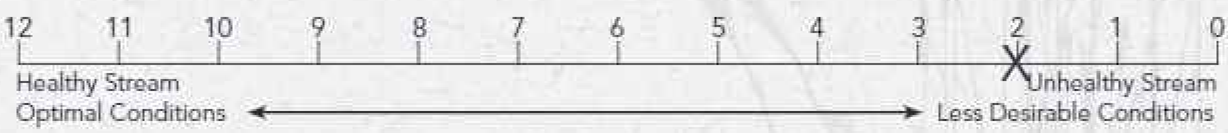
Site 1



Site 2



Site 3



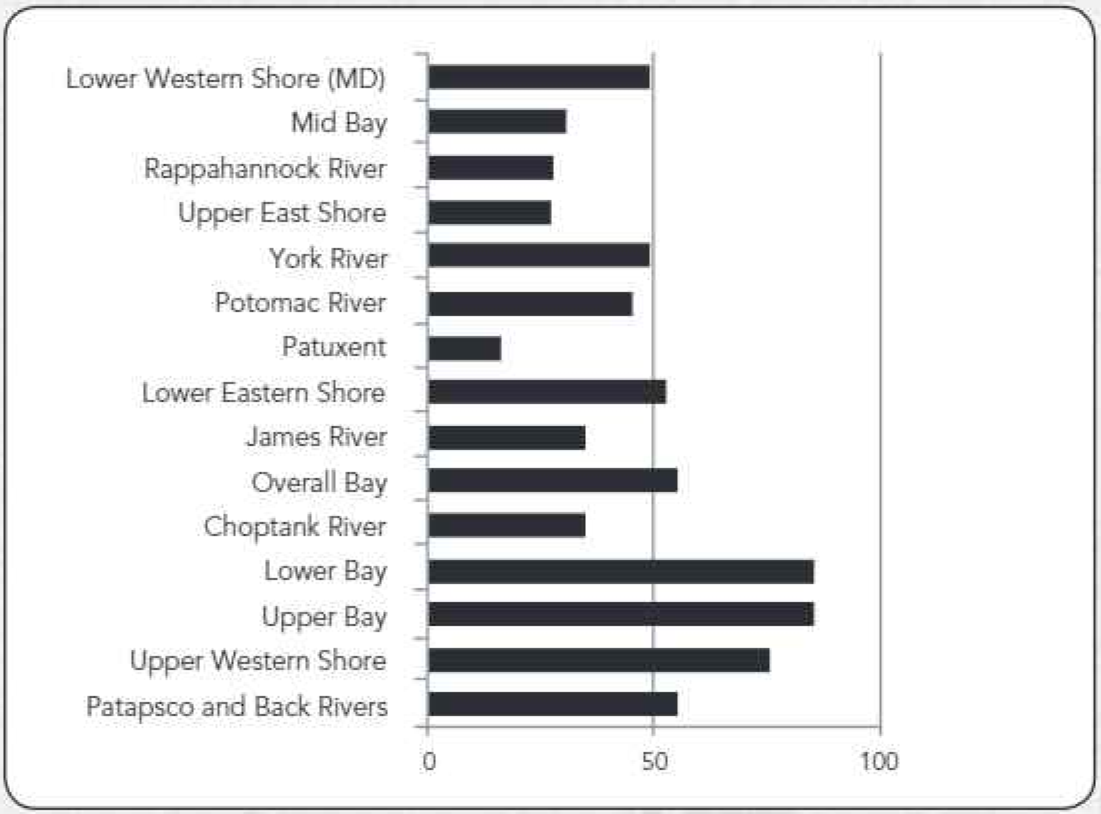
6. **Does the total number of macroinvertebrates found at a site give an indication of the water quality?**
Explain your answer.
Site 1 – 104, site 2 – 107, site 3 – 201. No – the total number of organisms found is not as important as the type of species found.

Now You See Them; Now You Don't

ELABORATION

7. Below is the Benthic Index of Biotic Integrity, with data collected by VERSAR under an agreement with the Chesapeake Bay Program's Chesapeake Information Management System (CIMS). This Benthic IBI evaluates the health of the benthic community in the tributaries of the Chesapeake, and reflects information gathered in a year. A score of "100" represents a very healthy tributary; "0" indicates a severely impacted tributary. Examine this graph and answer question 8.

8. Which major river in the Chesapeake Bay watershed had the most severely degraded benthic habitat? What do you think contributed to its poor health?



Benthic Index of Biotic Integrity by Chesapeake EcoCheck

Student Action Project: Take Action!

ELABORATION

BACKGROUND INFORMATION:

Students have looked at the problems caused by pollution in the Potomac River watershed. Recognizing a problem is the first step to solving it. The next step is to take what they've learned and apply that knowledge at the local level in the community.

During the field study in the park, students investigated a portion of their local watershed. This module and the field experience in the park were designed to create a Meaningful Watershed Educational Experience (MWEE). The MWEE process is student led with project-based learning. Inspiring stewardship through student action is the last step for a successful MWEE. The choices they make about how to interact with their environment in their watershed make a long-term difference, not only to the area in which they live, but also to the watershed as a whole.

TAKE ACTION!

Visit the BTW page of the Ferguson Foundation website to find information on how to take on a watershed action project. We provide some step-by-step instructions, but students provide the inspiration and execution.

Goals:

- To increase awareness of the need for individual environmental action.
- To act locally and get involved in a service project.

What Your Class Can Do:

When students are ready to take the challenge, there are many great ways they can get involved. The first step is to head to the Resource Library at the Ferguson Foundation website to check out potential student-led action projects.

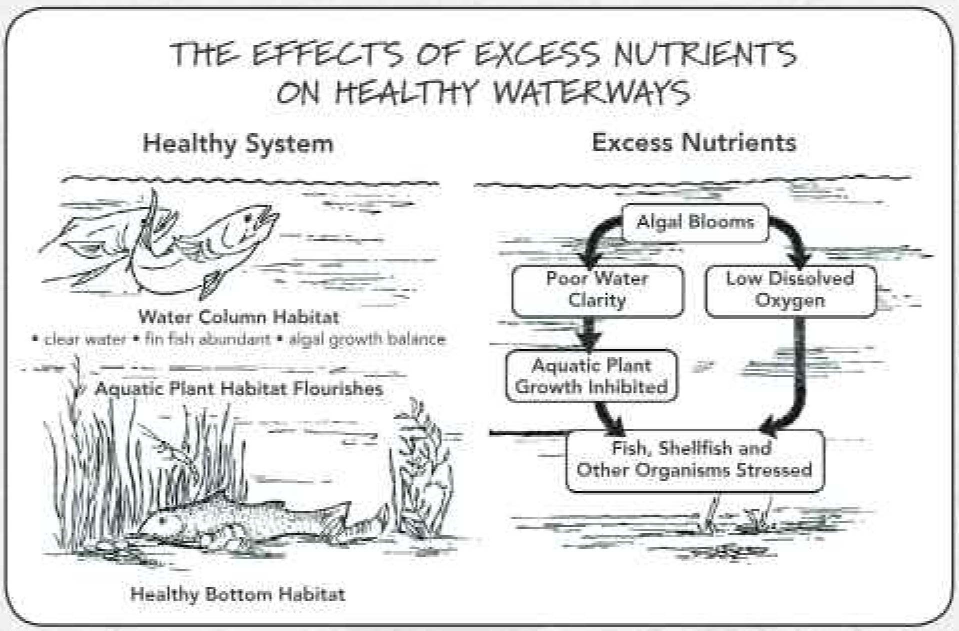
Resources

Nitrates and Phosphates: The Effects of These Pollutants on Aquatic Ecosystems

Nitrates and **phosphates** are two nutrients essential for aquatic organisms. Both occur naturally in soil, water, and air. There are also many nitrates and phosphates in human sewage and farm animal manure. Plant fertilizers used on lawns and farm fields contain large amounts of these substances. High-temperature burning of fossil fuels also adds nitrogen to the atmosphere.

Nitrates and phosphates can be pollutants in a waterway. In fact, they are the two major pollutants in the waters of the Potomac watershed. An aquatic ecosystem quickly gets out of balance when an excess of either one is washed in, and then **eutrophication** may occur. The literal meaning of eutrophication is "well-nourished." Eutrophication used in the context of an ecosystem means that the water is over-enriched with nutrients like nitrates and phosphates. This excess of nutrients causes accelerated growth of algae and higher forms of plant life. Thus, eutrophication describes an aquatic ecosystem that is out of balance due to natural aging or human influences.

A eutrophic body of water is rich in the nutrients that support abundant growth of aquatic plants at the surface. Microscopic producers, called algae, are an essential first link in the aquatic food web. When a waterway receives excess nutrients, an algal "bloom," or population explosion occurs. Because there are so many algae, the water turns a brownish or greenish color. This causes two major problems for other aquatic life. First, these algal blooms block sunlight from reaching beds of **submerged aquatic vegetation** (SAV). These are benthic plants that grow entirely under water, providing habitat, food, and oxygen for many aquatic animals. SAVs can die when light is reduced. Secondly, when these large masses of algae die, they sink to the bottom, where bacteria break them down. The bacteria use up large amounts of oxygen in this process. With less oxygen in the water, fish, crabs, and other aquatic life forms are harmed or killed. Eutrophication can have both temporary and more permanent effects on aquatic ecosystems. Eutrophication reduces biodiversity by encouraging the growth of nutrient-tolerant plants and algal species that tend to displace more sensitive species. Any decrease in biodiversity makes a food web more vulnerable to collapse.



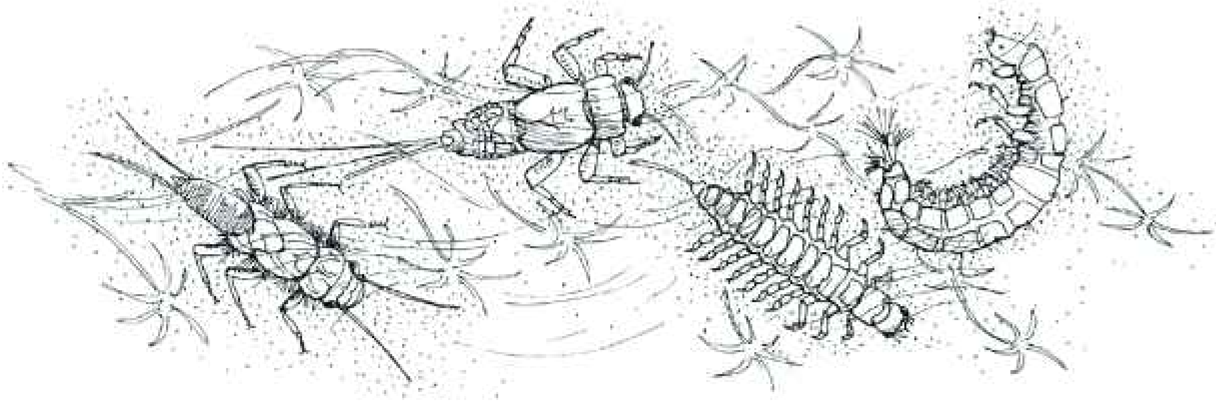
Nitrate and phosphate pollutants can come from two types of pollution based on the origin of the pollutants: **point source pollution** and **nonpoint source pollution**. Point source pollution can be traced to one certain point such as a pipe from a sewage treatment plant, a factory, or a power plant. Wastewater from these sources can contain toxic chemicals, phosphates, nitrates and other pollutants. Because of stricter regulations and better pollution-removal technology, point source pollution is much more easily controlled than nonpoint source pollution, which is pollution discharged over a wide land area that may be washed into a body of water.

Nonpoint source pollution originates from a source that is not easy to identify or from multiple sources, so these pollutants are very difficult to control. Nonpoint source pollution is sometimes called "runoff " because much of it is washed off the land by rain. Runoff includes fertilizers and toxic chemicals such as pesticides washing off lawns and farmland, oil, grease, litter from streets and parking lots, soil eroding off construction sites, and air pollutants washed into streams during rain events. Nonpoint source pollutants currently tend to have a much greater impact on life in streams and rivers than point source pollutants do.

Benthic Macroinvertebrates

Living things interact with their physical environment. When the physical environment changes, organisms must adapt or die. Therefore, the variety of organisms living in a stream provides the best indicator of a stream's overall ecological health. Organisms in the benthic zone, the area at the bottom of a body of water, filter plankton and organic particles from the water. Benthic macroinvertebrates are excellent indicator species because many are sensitive to pollution and low dissolved oxygen levels. A low level of dissolved oxygen, often caused by excess nutrients such as nitrates and phosphates, is the primary cause of benthic degradation, or loss of populations.

The benthic community includes a wide variety of organisms with diverse body shapes and adaptations for survival. Flowing water places great demands on the organisms living in it and the faster the water moves, the more difficult the living conditions. In fast streams, organisms must keep from being swept away by the current. Adaptations to help them hold on include having very flattened bodies (mayflies), having claws or hooks to hold on to the substrate (riffle beetles, sow bugs), or being able to build nests to anchor them to the substrate (caddisflies). Slower streams have more sediment, so organisms must be able to move to keep from being buried. These organisms often have the ability to burrow into the silt or mud (nematodes, annelids, and some species of mayfly and dragonfly larvae). The slower water also makes for easier swimming, so such creatures as freshwater shrimp and daphnia are able to swim freely.

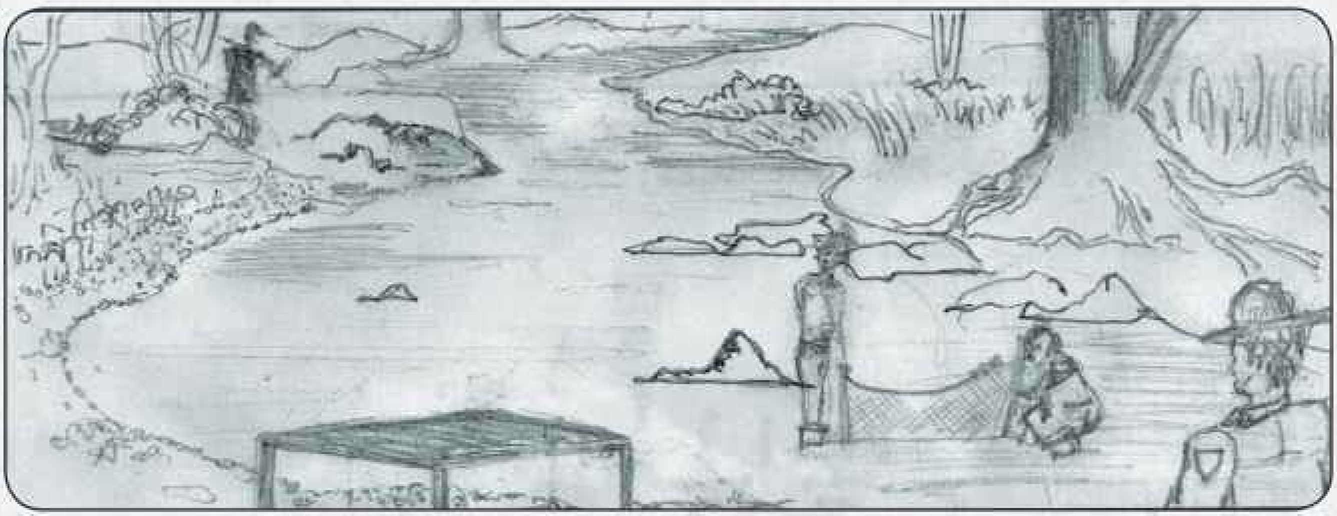


Stream Study

Aquatic ecosystems cannot be studied in isolation but must be viewed in relation to the surrounding area. The physical characteristics, or abiotic factors, of a stream are important in determining which organisms live there. One of the most important characteristics of any stream is its speed. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity and lower overall productivity. Speed will vary in different portions of the stream such as rapids, riffles, pools, or on the inner or outer edges of a bend.

Overall biological characteristics of the stream are also significant because plants and animals living near the stream may alter the stream environment. The runoff from a nearby barnyard may increase the nutrients in a stream. Trees on the stream bank may shade the stream and lower the temperature during the day. Leaves and branches that fall from bank vegetation into the water may serve as food for aquatic organisms. These three examples illustrate just a few of the biological influences that may affect the stream you are studying.

Making a sketch of the study site as it appears will help in understanding how land around the stream is used and may include such things as evidence of runoff, the amount and variety of plant life present, types of animals present, human impact on the area, and any evidence of pollution.



Stream Speed

The physical characteristics, or abiotic factors, of a stream are most important in determining which organisms live there. Stream speed is one of the most important characteristics of any stream. A fast-moving stream is usually cold, has good light penetration, lower nutrient concentration, less organism diversity, and lower overall productivity than slow-moving streams. A slow-moving stream is warmer, has less light penetration, a higher nutrient concentration, and more organism diversity. Speed will vary in different portions of the stream moving faster over riffles and the outer edges of a bend, and slower through pools and the inner edges of a bend.

Apparent Color and Odor

The apparent color of water is the result of dissolved substances and suspended materials. Thus, color provides useful information about the water's source and content. Pure water absorbs various wavelengths of light at different rates. Blue light and blue-green light are the wavelengths best transmitted through water, so a white surface under pure water appears blue. Natural metallic ions, algae and other forms of plankton, industrial pollution, and plant pigments from humus and peat may all produce color in water.

Determine the apparent color of water by lowering a white disc far enough below the water surface to produce a distinct color. Use the table of colors below to determine the source of the water color.

Color	Source
Blue	Low accumulation of dissolved materials and particulate matter (indicating low productivity)
Yellow or brown	Organic materials: humus, peat, decaying plants
Reddish or deep yellow	Algae
Green	Phytoplankton or algae
Yellow, red, brown, or gray	Soil runoff

The odor (smell or scent) of a water body is an indication of water content. Odor can be caused by the natural presence of algae and dissolved minerals. Odor can also come from municipal or industrial waste discharges, natural sources such as decomposing plants, or microbial activity. Odor affects the acceptability of drinking water, the aesthetics of water used for recreational purposes, and the taste of fish and other aquatic food.

Your nose is an excellent odor-detecting device. Collect a water sample in a wide-mouthed jar. Waft the air above the water sample toward you with your hand. Use the table of odors below to describe the nature of what you smell.

Odor	Nature of Odor
Aromatic (spicy)	Cloves, lavender, lemon
Flowery	Geranium, violet, vanilla
Chemical	Industrial wastes, chlorine, oil refinery wastes, medicinal, sulfur (rotten eggs)
Disagreeable/unpleasant	Fishy, pigpen, septic (stale sewage)
Earthy	Damp earth
Grassy	Crushed grass
Musty	Decomposing straw, mold

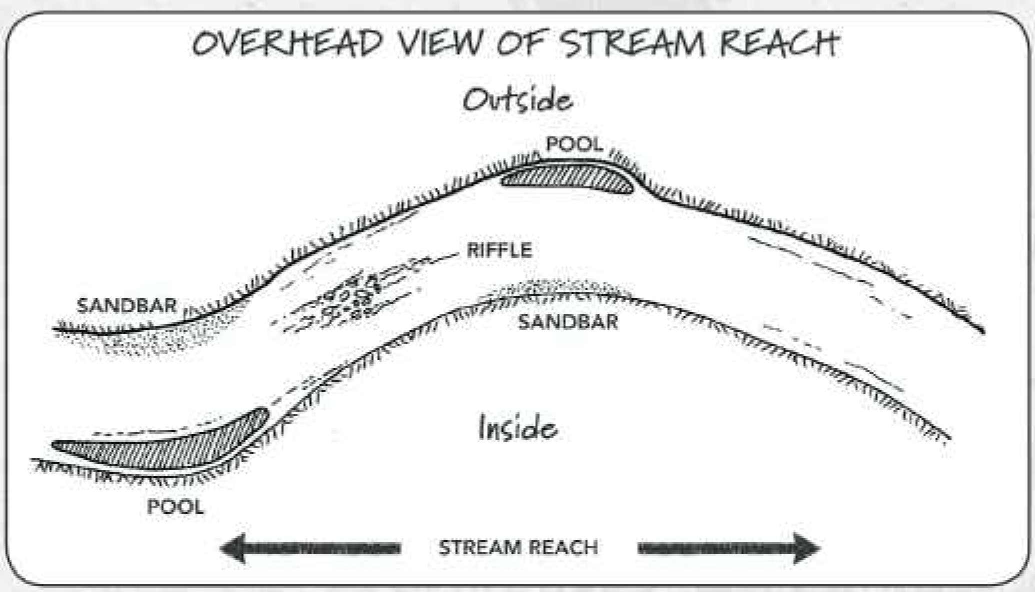
Riffles, Pools, and Bends

Rocks and debris in a stream may create shallow areas. Water rushes over these shallow areas to form an area of rapids with turbulent flow called a **riffle**. Riffles aerate (add oxygen to) the water and provide habitat for many invertebrates.

A **pool** is a deeper area of water that is quiet and often has no visible flow. Pools provide deeper areas for fish and other larger aquatic organisms. Streams that have many pools and riffles are able to support more life and a greater variety of species than streams that do not.

A **bend** is a change in the direction of the stream channel and the flow of water. Larger, slow-flowing rivers usually have more bends that can provide different habitats. The cutting action of the water at bends provides regions of varying depth and water velocity. Frequently, there is erosion of the bank on the outside of a bend and sediment deposition on the inside of the bend.

Resources

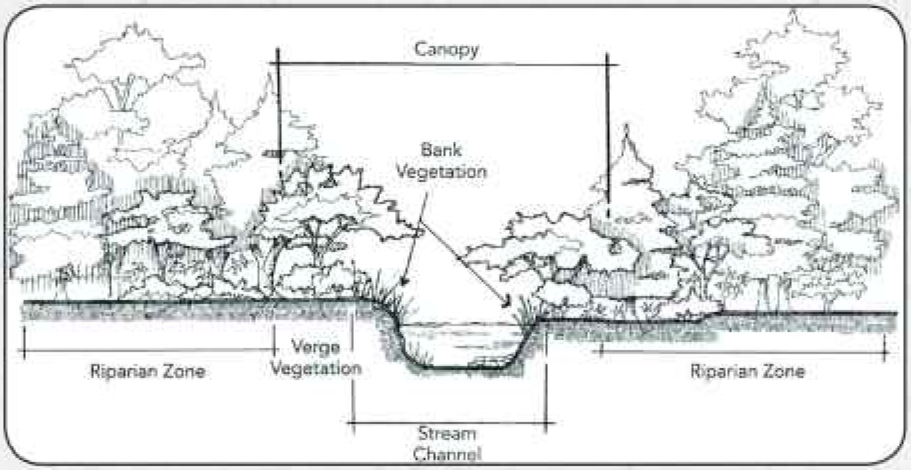


Land Vegetation

The condition and composition of **vegetation** (e.g., trees, shrubs, grasses) around a stream is a good indication of the health of the aquatic environment. Vegetation provides a natural buffer against erosion and prevents transport of sediments into streams. When vegetation around a stream is degraded or absent, there is less protection for the stream. Deterioration of water quality and habitat for aquatic plants and animals may occur.

A **riparian** area refers to land adjacent to streams, rivers, or water bodies that directly affects and is affected by the water. Trees, shrubs, and other types of vegetation make up the riparian area along waterways. These plants prefer moist to very wet soil and can withstand the disturbance of water flowing over and around them. Riparian vegetation along riverbanks provides a unique habitat in mutual balance with the river channel.

The riparian area includes bank vegetation and verge vegetation. **Bank vegetation** refers to trees, shrubs, grasses, and other vegetation actually growing on the stream bank (sides of the stream channel). The trees from this area overhanging the stream form the stream **canopy**. Bank vegetation provides food and shelter for aquatic organisms in the form of fallen twigs, leaves, fruits, flowers, and branches.



Verge vegetation starts at the top of the bank and extends to the next major line of vegetation or to the point of a change in land use. Excellent verge vegetation is a wide corridor of undisturbed native vegetation. As verge vegetation deteriorates the corridor of vegetation narrows and non-native plants replace native vegetation. In areas of very poor verge vegetation, there is no native tree or shrub layer, resulting in patchy growth or bare soil.

The vegetation in the riparian area affects many features of the waterway ecology such as light, temperature, and bank stability. It acts as a physical buffer to reduce runoff, and is especially effective as a sediment trap. It forms habitats for birds and small mammals, provides overhanging shelter for fish, serves as a place for emergent insects to rest, feed, and lay eggs, improves water quality by filtering runoff before it reaches the water, and promotes sediment deposition on the land. Riparian vegetation slows floodwaters and reduces the total volume of water entering the stream through root absorption. It provides opportunities for recreational activities such as fishing, hiking, bird watching, picnicking, and camping. Riparian vegetation is vulnerable to destruction by natural change and careless human management. It is as important to protect as the river channel itself.

Climate Change

Climate change, often referred to as global warming, is one of the major human issues of our time. Global warming, or the average rise in the Earth's temperature, impacts the climate all over the planet. Climate change includes changes in patterns of temperature, precipitation, humidity, wind, and seasons. It refers to more than just a change in the weather. It refers to accelerated changes in climatic variables over a long period of time. This process has multiple impacts on the planet's ecosystems and human welfare.
The difference between weather and climate is a measure of time: climate refers to weather patterns over the course of decades or centuries. Under climate change, many regions may be susceptible to more frequent droughts, heavier rains, or higher temperatures than normal.

Scientists know that human activity is causing climate change. Anthropogenic, or human-made, activities that are strong contributors to climate change include the burning of fossil fuels to create electricity or to power a car or bus, or removing forests from large tracts of land. The warming influence is primarily to the increase in three key heat-trapping greenhouse gases in the atmosphere: carbon dioxide, methane, and nitrous oxide.

Excess carbon can cause regional climates to change, and can create secondary effects such as sea level rise and more extreme weather events. The interconnectedness of the Earth's systems means that any significant change in one of the systems, like the climate, impacts other interdependent systems.

- **Excess carbon dioxide (CO_2)** is the by-product of burning fossil fuels, such as gas in cars and other modes of transportation, electricity to power equipment and lights in our homes and offices, and machinery in industrial buildings.
- **Methane (CH_4)** is the by-product of the decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion.
- **Nitrous oxide**: While nitrous oxide is produced naturally in soil by microbes, excessive N_2O is the result of applications of organic and synthetic fertilizers on cropland and other managed landscapes such as golf courses and gardens.

The accumulation of these gases in the atmosphere causes what is known as the "greenhouse effect." These gases absorb infrared radiation in the atmosphere and trap the heat. Some of the heat flowing back toward space from the Earth's surface is trapped by water vapor, carbon dioxide, and ozone and then re-radiated or reflected back toward the Earth's surface. As the atmospheric concentrations of greenhouse gases rise, the average temperature of the lower atmosphere increases gradually.

ENVIRONMENTAL JUSTICE

The influences of warming temperatures have stronger impacts on vulnerable populations of minorities, people 25 and older with no high school diploma, elderly people, and low-income communities, who have had higher energy bills through the increasing use of air conditioning. These concerns are part of environmental justice, the the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income.

In 2023, the Fifth National Climate Assessment reported environmental justice concerns through climate hazards such as pollution, sea-level rise, extreme weather events, and warmer temperatures. They are affecting the U.S population, but vulnerable communities that lack access to health care, social services, and financial help face the highest risks. The COVID-19 pandemic in 2020 strained these resources, as the demand for medical care for individuals becoming ill and increasing heat waves and wildfires across the nation set back federal response to disasters. These type of climatic events can affect the well-being of communities. However, communities across the Potomac River Watershed, such as in Washington D.C and Baltimore, Maryland, have gathered to bring awareness to issues within their communities and advocated for change. In 2016, the historically black community of Brandywine, Maryland fought against having another power plant placed in their community, which would emit harmful pollutants into the air. In 2022, the power plant was found to be under violation of air pollution standards. The money for the power plant instead went toward planting trees in the community, as well as funded a program that would bring an outdoor skills boot camp for youth in the area.

HOW WILL CLIMATE CHANGE AFFECT THE ECOSYSTEMS IN THE POTOMAC RIVER WATERSHED?

The effects will depend on our choices today. Temperatures in the Potomac River watershed have already warmed by nearly 2° F since 1960 with warm record breaking years in 2016 and 2023. These temperature increases will impact us directly and indirectly:

- Extreme rainfall and associated floodings that may affect water availability in the region.
- The length of the winter snow season would be reduced to a week or two, which means smaller snowmelt to feed the rivers in the spring. Meanwhile, the hot summer conditions would arrive up to three weeks earlier and last up to three weeks longer in fall.
- Effects of environmental stressors and pollution are disproportionately impacting vulnerable communities.
- Cities that today experience few days above 100°F each summer would average 20 such days per summer. Certain cities would average nearly 30 days over 100° F. This can create stress on people with asthma and other health conditions that are aggravated by the heat.
- Sea level along the Mid-Atlantic coast is projected to rise more than the global average, making the floodplains on the Potomac bigger than they are now.
- During storm events, the plants and animals in low-lying, inland areas will be inundated. This effect is exacerbated by the lack of wetlands in these areas. For example, Dyke Marsh Wildlife Preserve, part of George Washington Memorial Parkway, is surrounded by hard, paved surfaces (the roads and buildings around the park). Instead of being able to move inland under the new flooding regime, the marsh will be under water more often, and many species will be unable to survive. Floodplains everywhere will fill during stronger storms; models show that a major storm could breach the levee on the National Mall and flood much of the Ellipse.
- Aquatic ecosystems are showing signs of acidification as a result of dissolved CO2, which is changing the pH balance of the oceans. The Potomac River has its headwaters in the Blue Ridge Mountains, where regional acidification from wet and dry atmospheric deposition has affected aquatic resources over t he last few decades. As climate change progresses, these upland streams will experience temperature increases and changes in fluvial regime, or the patterns of flow in the streams.

Flooding around the National Mall. Credit: Evan Vucci

EFFORTS FOR THE CHESAPEAKE BAY

Work to protect the Chesapeake Bay Watershed, our largest estuary and most productive in the world, began in the late 1970s, culminating in the 1987 Chesapeake Bay Agreement, which established pollution reduction goals. In 2014, a Chesapeake Bay Watershed Agreement had participation from all watershed representatives, outlining ten goals for Bay restoration. This agreement was amended in 2020.

The 2022 State of the Bay report highlights progress in restoration efforts, including land and forest buffer conservation and the reopening of fish passages through removal of barriers like dams and reservoirs. However, almost 250,000 acres of tidal wetlands and coastal lands across the region are being threatened by sea level rise, adding difficulties to restoration efforts. Challenges still remain, particularly in combating agricultural and urban pollution worsened by climatic change.

Despite challenges, there are reasons to be hopeful about resorting the 64,000 square miles of land and water within the Chesapeake Bay Watershed. The 2014 agreement has fostered scientific understanding, partnerships, and resource allocation, resulting in improved river health and species recovery. Successes include:

- In 2023, dead zones, areas with little to no oxygen, in the Chesapeake Bay were the smallest they have been since 1985.
- The Chesapeake Bay Program has restored oyster habitat in eight tributaries of the Bay and is expected to complete work on three more rivers by 2025. In 2022 and 2023, Virginia and Maryland had a record-breaking amount of oysters harvested.
- The Potomac and Patuxent Rivers in Maryland show a long term trend of decreasing nitrogen and phosphorus pollution. This indicates the rivers are getting cleaner and habitat is improving for wildlife and is safer for recreation.
- 67% of the streams in the watershed are considered healthy in 2017 which is up from 57% in 2005. The Partnership is on track to reach the goal of 70% of healthy stream miles by 2025 as set by the 2014 Chesapeake Bay Watershed Agreement.

Furthermore, funding from the Infrastructure Investment and Jobs Act (2021) has allowed the US Environmental Protection Agency to support organizations in planting trees, restoring wetlands, upgrading water treatment plants, increasing research and much more, benefiting communities affected by water pollution and climate-related disasters.

AQUATIC ECOSYSTEMS

In addition to rising water level, the change in water temperature will have an impact on the sustainability of certain aquatic species due to increasing pH levels and other indirect impacts. According to the U.S Geological Survey, the Chesapake Bay watershed's average annual stream temperatures have increased by 1.1°C in the past six decades. For the diamondback terrapins, the sex of the offspring is determined by temperature during incubation. Higher nest temperatures produce more females; lower temperatures produce more males. The imbalance of males and females has the potential to alter the sustainability of this species.

Another issue for the diamondback terrapin is the availability of nesting habitat. As sea level rises, the loss of nesting beaches in the Chesapeake will confront this species.

Cold-water-loving species, such as the brook trout, will be harmed as water temperatures rise. Extreme hydrologic events – big storms and the runoff they create – are expected. The changes in the landscape these storms create will favor the establishment and spread of non-native and invasive aquatic species.

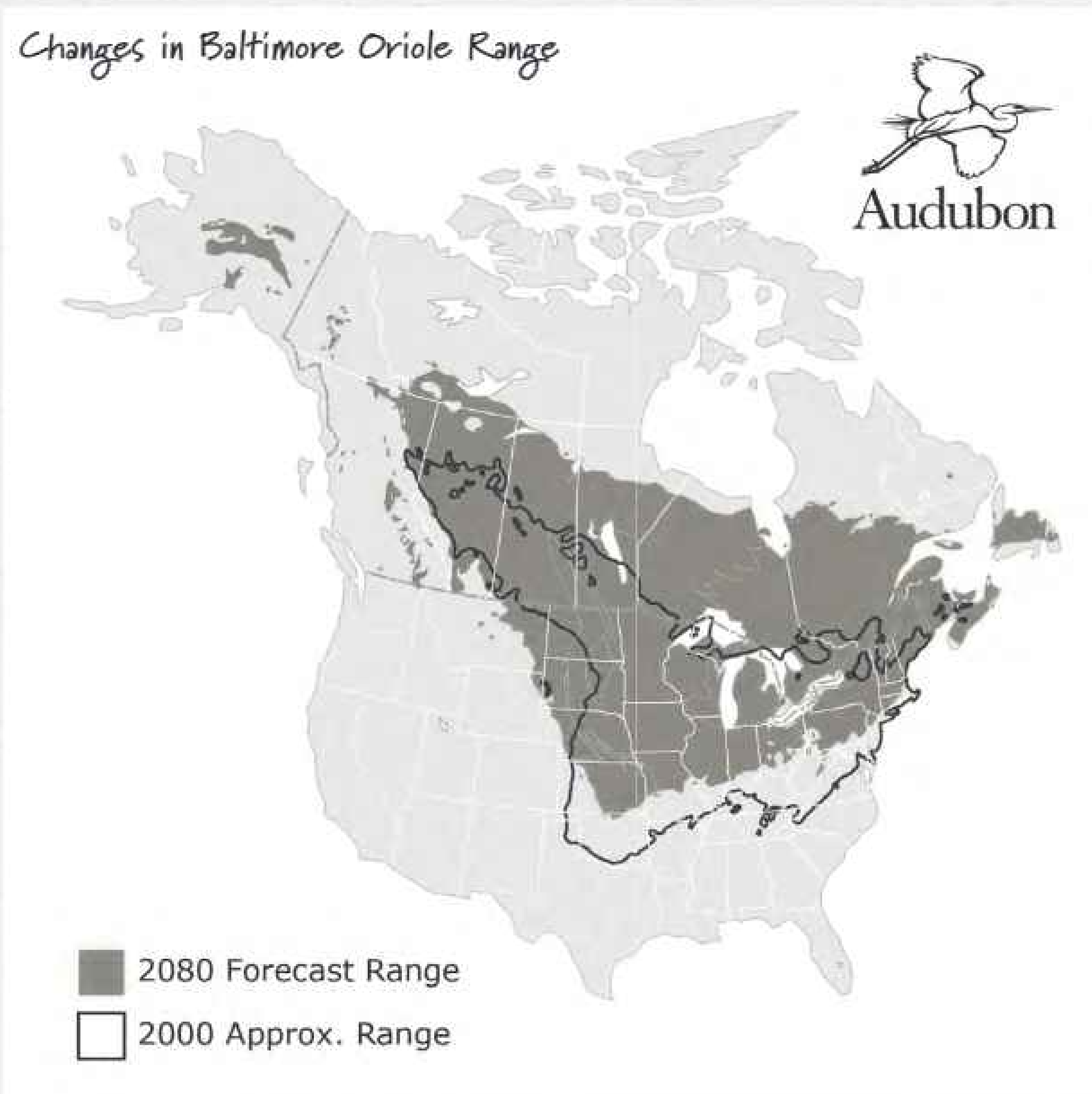
Benthic macroinvertebrates respond more quickly and predictably to changes in the environment, such as increased water temperatures, than vertebrates such as fishes and amphibians. You may find vastly different species of macroinvertebrates on a field study in future years.

LIFE CYCLES AND SPECIES INTERACTIONS

Timing is a matter of life and death in nature. Scientists refer to this as phenology or the study of plant and animal life cycle events throughout the seasons and over time. In the case of flowering plants, these life cycle events, or phenophases, include leaf budburst, flowering (from first flower to last flower), fruiting (from first ripe fruit to last), and senescence (leaf shedding), among others. Phenophases commonly observed in animals include molting, mating, egg laying or birthing, fledging, emergence from hibernation, and migration.

Life cycles are changing. A study of weather data over the past 100 years shows that our growing season is increasing, with the first frost date arriving an average of a week later than at the beginning of the last century, and the last frost date coming two weeks earlier in the spring. This means that plants are beginning to bloom sooner and that the fall freeze is allowing plants to continue to grow much later in the fall.

If migratory species like birds are cued to migrate by the length of day, which hasn't changed over the century, their food sources along their route may be responding to temperature in addition to light cues. So, critical food sources may not be timed to be most abundant when the migratory birds pass through. The map below shows the range, the geographic area in which a species lives, of the Baltimore oriole in 2000 and how its range may no longer be in Baltimore by the year 2080 as the climate conditions they need to survive would shift north.



INVASIVE FLORA

Warmer temperatures also favor invasive plant species. Invasive species are those that have been introduced into an ecosystem from elsewhere in the world. While it's tempting to think that every green living thing is good, plants introduced from other parts of the globe pose a serious threat to our native plant and insect species. Non-native invasives are species out of place without natural biological controls, so they easily spread and take over a habitat, often choking out native species that have a higher food value for local insects, birds, and mammals. As a result, if high food value insects like caterpillars, which have evolved to prefer specific plants in their habitat, are unable to find the plants they need to sustain their populations, the impact will be observed higher up in the food chain. Without these high protein meals, bird species that depend on these insects for sustenance are affected during the migratory season.

WHAT CAN YOU DO?

When each person does his or her part to reduce their impact on the climate, the collective efforts make a difference. For example:

- Bring a trash-free lunch to school. Pack your lunch in reusable containers rather than single-use sandwich bags, which are made of fossil fuels.
- Recycle and use recycled products, which require less energy to produce.
- Walk or ride your bike whenever possible instead of using transportation that relies on fossil fuels.
- Rather than do your errands in a series of small trips, combine them into one single trip to reduce the overall amount of fuel consumed.
- Buy locally grown food at farmer's markets, when possible, rather than food shipped in from other parts of the country and the world.
- Use the front and back of your paper to reduce the number of trees (which absorb carbon dioxide and produce oxygen) that need to be cut.

INVESTIGATING STREAM HEALTH WITH THE MARYLAND BIOLOGICAL STREAM SURVEY from The BayNet by the Department of Natural Resources

ANNAPOLIS, Md. – How can the Maryland Department of Natural Resources (DNR) tell whether a stream is healthy or degraded? State scientists start by looking for critters. Every year scientists from the Maryland Department of Natural Resources crisscross the state with notebooks, nets, and other equipment looking for insects and other wildlife as part of the Maryland Biological Stream Survey. The scientists collect and analyze bugs, fish, and other indicator species to develop a score that can show whether a stream is biologically healthy or not. Every year scientists from the Maryland Department of Natural Resources crisscross the state with notebooks, nets, and other equipment looking for insects and other wildlife as part of the Maryland Biological Stream Survey. The scientists collect and analyze bugs, fish, and other indicator species to develop a score that can show whether a stream is biologically healthy or not. On a crisp fall day in October, as part of DNR's Science Week, several scientists from the stream surveying team demonstrated how the process works at a tributary stream of the Patapsco River in Ellicott City.

It starts with the benthic macroinvertebrates. These are aquatic animals such as mayflies, caddisflies, dragonflies, stoneflies, and crayfish. Their presence in a stream is one factor that can indicate healthy stream water quality. DNR Biologist Jackie Sivalia demonstrates to Secretary Josh Kurtz how a D-Net is used to catch macroinvertebrates, and explains how they help her and other scientists evaluate the overall health of the stream.

"The presence of benthic macroinvertebrates provides us with long-term insight into the health of stream, since they must deal with the conditions day-in-and-day-out; whether the water is flowing with sediment from a strong rain storm or baking in the hot summer sun," said Kyle Hodgson, a DNR biologist. "These creatures give us a deeper insight into overall water quality conditions than a water quality sample taken at a specific time can provide. I like to think of a benthic macroinvertebrate sample of a stream as a movie and a water quality sample as a snapshot."

At the Patapsco tributary, scientists used a D-net — so named because its frame is shaped like the letter "D" — to scoop the leaves from the stream bed and sift for insects and other critters. That day, they were able to find a dragonfly larva and a few other insects. Certain types of benthic macroinvertebrates such as mayflies, stoneflies, and caddisflies tend to be intolerant of pollution, and therefore are less likely to be present in streams impacted from pollution sources such as suburban or agricultural runoff.

Researchers use the distribution and abundance of specific macroinvertebrates to create a Benthic Index of Biotic Integrity (BIBI) rating for streams. This rating enables them to compare different streams. The Maryland Biological Stream Survey posts the BIBI scores for streams in an interactive map on the DNR website. Streams are generally rated "poor" in more developed areas of Maryland that receive pollutants from stormwater runoff and other human activities, while streams rated "good" tend to be in less developed areas.

Scientists collecting data for Maryland Biological Stream Survey

Student Pages

Bridging the Watershed

Water Canaries Datasheet

Date: ____________

Teacher: ____________

Park: ____________ Study Site: ____________

Park Rangers & Educators: (one per row)	Group Members: (one per row)

Latitude: North ____________ ° Longitude: West ____________ °

Why is it important to know the latitude and longitude?

	Yesterday	Today
Air Temperature	°C	°C
Cloud Cover	☐ Clear ☐ Partly Cloudy ☐ Cloudy	☐ Clear ☐ Partly Cloudy ☐ Cloudy
Precipitation	☐ None ☐ Rain ☐ Other	☐ None ☐ Rain ☐ Other

How could weather affect today's field study?

Water Color ____________ Water Odor ____________ Water Temperature ____ °C

Stream Bottom: ☐ Rocky ☐ Sandy/Gravel ☐ Silty

Stream Canopy: ☐ Full Shade ☐ Partial Shade ☐ Sun

How are water temperature, stream bottom, and canopy related?

Stream Speed:

Trial 1		Seconds
Trial 2		Seconds
Trial 3		Seconds
Average		Seconds (Add all 3 Trials and divide by 3)

Stream Speed measured with digital probe: ____________ ft/s

Use the average time from above in the calculation below to determine average stream speed

10m / ____ [average time]= ____________ meters/second

Because we test speed only at the surface of the stream, we use a 'fudge factor' of 0.8 to adjust for an overall stream speed. Use the average speed from above to find the overall stream speed:

Average Speed x 0.8 (fudge factor) = ____________ meters/second

Sketch the study site, showing all details that affect your field study:

Macroinvertebrate Collection (Write in numbers only)

Alderfly, Fishfly, Hellgrammite	
Aquatic Sowbug	
Aquatic Worms	
Beetle & Water Penny	
Blackfly	
Clam	
Cranefly (Truefly)	
Crayfish	
Common Netspinner Caddisfly	
Damselfly & Dragonfly	

Flatworm	
Gilled Snail	
Leech	
Lunged Snail	
Mayfly	
Midge	
Most Caddisflies	
Scud	
Stonefly	

Other/Notes:

Bridging the Watershed • www.fergusonfoundation.org

Procedure and Tables for Data Analysis

1. Refer to the Macroinvertebrate Survey Data Sheet. Determine the number collected for each species and record in the "Number Collected" column in Table V: Total Index Value for Stream.

2. Enter "Number Collected" for each species in the block(s) under the headings "Sub-Categories A-F" to the right of the species name. Because of the pollution tolerance level of each category of species used in computing the water quality, you will need to copy the "Number Collected" two or three times for certain species.

3. Total the numbers in all columns and write the totals in line 3.

4. Compute the percentage of the total number of organisms for each column and write in line 4.

5. Use the percentages computed in step 4 to determine an index value for each sub-category. Consult Table IV: Index Values assigned to Sub-Categories. Determine an index value of 2, 1, or 0 by finding where the percentage of each sub-category best fits. Record index values in line 5.

TABLE IV: INDEX VALUES (%)

Sub-Categories	2	1	0
A	> 32.2	16.1 – 32.2	< 16.1
B	> 6.4	3.2 – 6.4	< 3.2
C	< 19.7	19.7 – 34.5	> 34.5
D	< 0.3	0.3 – 1.5	> 1.5
E	< 46.7	46.7 – 61.5	> 61.5
F	< 5.4	5.4 – 20.8	> 20.8

> greater than
< less than

6. Add all index values to obtain a total index value for the stream and write the value in line 6.

7. Mark an "X" on the scale below Table V, corresponding to your total index value, to determine your stream's health.

TABLE V: TOTAL INDEX VALUE FOR STREAM

	Species	1. Number Collected	2. Sub-Categories					
			A	B	C	D	E	F
Sensitive	Mayfly larvae							
	Stone Fly larvae							
	Most Caddisfly larvae							
	Beetles (adults & larvae)							
Somewhat Sensitive	Dragonfly larvae Damselfly larvae							
	Common Netspinner larvae							
	Crayfish							
	Gilled Snails							
	Aquatic Sowbugs							
	Scuds							
	Clams							
	True Fly larvae							
	Hellgramites, Fishfly larvae, Alderfly larvae							
Tolerant	Lunged Snails							
	Black Fly larvae							
	Midge larvae							
	Aquatic worms							
	Flatworms							
	Leeches							
3. Sum of numbers in each column								
4. Percentage of total number of macroinvertebrates in each sub-category								
5. Index value for each sub-category								
6. Total index value for stream								

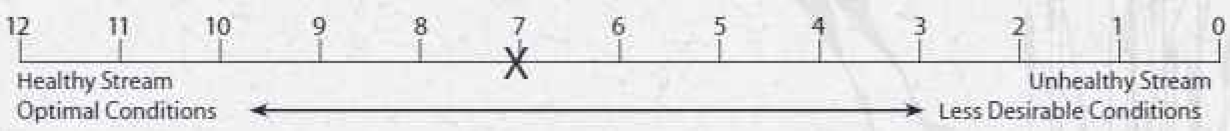
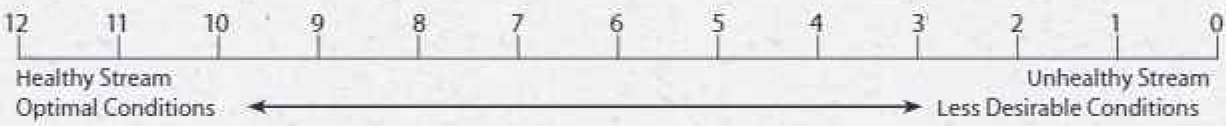


TABLE VI: CLASS TOTAL INDEX VALUE FOR STREAM

Sub-Category	Class Groups					Class Average
	1	2	3	4	5	
A						
B						
C						
D						
E						
F						
					Total index value for stream	

Hint: Class total index value for stream is the sum of class averages.



Group Members ______________________________ Date ______________

Performance Criteria	Assessment		
	Points	Group	Teacher
1 All group data are entered, and an average total index value for the group is accurately determined.			
2 All class data are entered, and an average total index value for the class is accurately determined.			
3 The summary report begins with a detailed description of the study area and weather conditions.			
4 Along with the summary of class data and total index value, a descriptive assessment of the health of the stream is included.			
5 Individual water quality parameters that exceeded significant levels are noted, and possible reasons are proposed.			
6 The summary is clear and concise, and accurately reflects the findings of the study.			
7 Scientific terminology and concepts are accurately explained and applied to illustrate major points of the report.			
8 Visual aids (photographs, charts, graphs, and drawings, etc.) enhance understanding of the text.			
9 Visuals are clearly titled, labeled, and referenced within the text.			
10 Language used in the report is purposeful, descriptive, and appropriate for the intended audience.			
Total			

Teacher Comments:

Now You See Them; Now You Don't Tables and Procedures

PROCEDURE AND QUESTIONS

1. Look at the map of the Potomac River Watershed. **Find and label the Potomac River**

2. Macroinvertebrates in the Potomac River tributaries are monitored on a continuing basis. Refer to Table VII: Macroinvertebrate Species Count - Potomac River. The data was compiled from three different tributaries along the Potomac River.

3. For each of the three sites calculate the percent of total number and determine the index value for each sub-category. Add all sub-categories at each site to determine the total index value.

4. Place an "X" on the scale below Table VII marked 0 to 12 to get an idea of stream health at each site.

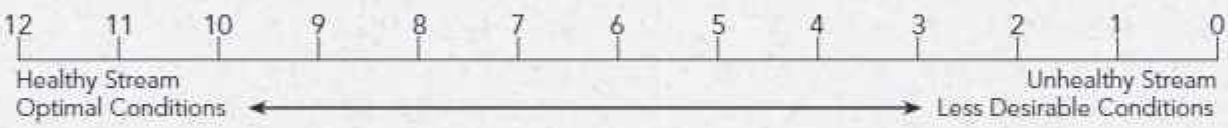
5. At the time of the sampling, one of the sites was under environmental stress from wastewater runoff. Which site do you think it was? Use the data from the three sites to support your answer.

6. Does the total number of macroinvertebrates found at a site give an indication of the water quality? Explain your answer.

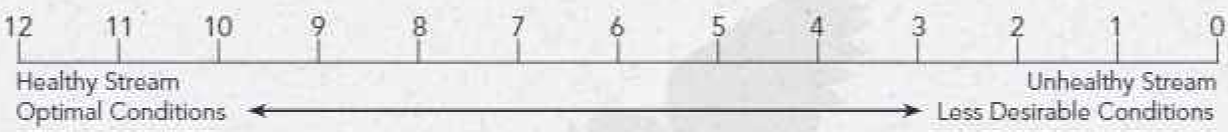
TABLE VII: MACROINVERTEBRATES SPECIES COUNT — POTOMAC RIVER

	Site 1			Site 2			Site 3		
Sub-Category	Number Collected	Percent of Total Number	Index Value	Number Collected	Percent of Total Number	Index Value	Number Collected	Percent of Total Number	Index Value
A	39			30			2		
B	9			4			1		
C	26			6			5		
D	1			7			7		
E	15			27			88		
F	14			33			98		
Total (all sub-categories)	104			107			201		
	Total Index Value for Site 1			Total Index Value for Site 2			Total Index Value for Site 3		

Site 1



Site 2



Site 3