Alice Ferguson Foundation's

BRIDGING THE WATERSHED

POTOMAC RIVER WATERSHEDS

Water, Water, Everywhere

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

POTOMAC RIVER WATERSHEDS

Water, Water, Everywhere

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"National Park Labs" is a program of the National Park Service, the National Park Foundation, and Toyota USA Foundation. These model programs, the first of their kind, provide high school students with opportunities to study real-world science in the national parks and foster stewardship of park resources.

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An Overview of the Bridging the Watershed Program

Bridging the Watershed is an environmental education program for middle– and high–school students designed to promote understanding and stewardship of the Potomac River watershed. The Alice Ferguson Foundation operates this program in partnership with the National Park Service - National Capital Region and area school districts. Teachers and students have the opportunity to use 14 national parks as outdoor learning laboratories. Part of each module is a field study in one of these national parks, where students use the processes of science to learn about the health of the natural resources in the Potomac River watershed. These processes include analyzing the water quality of streams, identifying benthic macroinvertebrates, assessing runoff and suspended sediment in waterways, quantifying the kinds of trash found in the watershed, and conducting a survey of exotic and native plants to discover the impact of human activity.

One of the main goals of the BTW program is to make the activities relevant to students' lives, serving to bridge the divide between science in the classroom and science in the natural world. Many students have had little or no contact with the natural environment or with national parks. This program aims to provide students with exposure to science in a natural setting, broadening their understanding of scientific study. The activities are based on sound pedagogical principles and correlated to national, state, and local education standards. As a result, the activities in all six modules are inquiry-based and "hands-on/minds-on," encouraging students to experiment and then draw conclusions based on the results of the experiment. The program follows the constructivist pedagogy and uses the five Es of the teaching/learning cycle – Engage, Explore, Explain, Elaborate, and Evaluate – as its structure. All activities are student directed, with the teacher acting as the guide and facilitator.

Each of the modules focuses on a particular discipline of science: chemistry, biology, Earth science, or environmental science. Nonetheless, the activities are interdisciplinary with a major emphasis on math. While each module is meant to stand alone and be used primarily in the science class on which it focuses, teachers may find it helpful to use more than one module with their students. All modules contain pre-field study activities and preparation, a half-day field study in a national park, and follow-up analysis and reflection on the experience. At the conclusion of each module, students are encouraged to engage in an action project during which they can apply what they have learned about the environment to their own community or in a national park.

The Six Core Modules in the BTW Curriculum: The following summaries describe the six modules in the BTW curriculum. Included in the summary is the science discipline or disciplines to which the module is most closely related. Park-specific modules, which fully integrate the scientific concepts of a module with the story of a specific park, are found online. An overview module introduces general watershed and climate change concepts that may be used as a prelude or supplement to any of the other five modules.

- ***Potomac River Watersheds: Water, Water, Everywhere.*** This module provides an introduction to Bridging the Watershed, our methodology, and basic activities to introduce students to watersheds. This module also provides students with an understanding of the complex issues of climate change and the greenhouse effect.

- ***Watershed Watchdogs: Assessing Water Quality.*** Chemistry or environmental science students study nine parameters that will help them determine the Water Quality Index (WQI) for the Potomac River or one of its tributaries.

- ***Water Canaries: Assessing Benthic Macroinvertebrates.*** Students in biology or environmental science classes learn to identify benthic macroinvertebrates and then determine water quality by using the sensitivity ratings for the macroinvertebrates found in the stream during their field study.

- ***Exotic Invaders: Assessing Exotic Invasive Species*** Biology and environmental science students study the importance of biodiversity, learn the basics of plant identification, and explore the extent of exotic plant invasion in a local national park.

- ***Don't Get Sedimental: Runoff and Sediment in the River***. Students in Earth science or environmental education classes explore the impact that runoff from increasing development has on the watershed.

- ***Talkin' Trash: Make a Litter Difference*** Students in any science class examine the impact of trash in their watershed. They learn how trash reveals a lot about the lifestyle of the residents that create it, how trash impacts the environment, what to do with all the trash we produce, and how personal choices can make a difference.

Additional Components of the BTW Program: The BTW program includes more than modules for students. The program also offers training institutes for teachers and a website with additional activities. The website contains authentic data collected by students who have completed the program. More information about these two components follows.

Summer Teacher/Ranger Institute. Held at participating national parks, teachers work with park rangers to explore the modules in depth. The institute is held every summer. Teachers visit multiple parks and learn several of the six modules. They are paid a daily stipend and can receive graduate credit. Only teachers who have participated in the institute are eligible to bring students to a Bridging the Watershed program in a national park.

BTW Website. The interactive website, found at fergusonfoundation.org, provides an essential link to enrich and reinforce the educational experience of the program. The site provides visitors with online activities to prepare for a visit to the park, valuable knowledge about parks and their natural resources, or the ability to receive an electronic copy of the BTW newsletter. Students' field data is uploaded by our educators to AFF's Sharepoint database, making the website a valuable community resource of watershed data. Teacher pages provide information about upcoming events, workshops, and the annual BTW institute.

- **Timeline of the Potomac River Watershed.**The timeline can be used by history or social studies classes, as well as by science students, to learn many interesting, often little-known facts about our past. The timeline begins with Native American pre-history and continues to the present day. Major events that have affected the watershed are interspersed with colorful sidelights, delighting "trivia" fans as well as historians.

- **Online Interactive Activities.** "Swim for Your Life" is an interactive simulation game intended to appeal to students in middle and high school. During the game, virtual anadromous fish leave the open ocean each spring and travel into estuaries, coastal and freshwater rivers, and creeks to release their eggs. As the season moves into late summer and early fall, the juvenile fish leave the shelter of the upper estuary and begin a journey to the open ocean from which their parents came. During this trek, the fish encounter many perils, and not all of them will survive to reproductive maturity.

- **Macroinvertebrate and Plant Identification Activities.** Students of all ages learn basic techniques biologists use to classify organisms. The macroinvertebrates in two streams are identified with a key and then used to assess the relative health of their stream. Students learn basic invertebrate anatomy as well as how to use a key.

  The plant identification key is unique in that it uses leaves as a starting point rather than flowers. Since a large percentage of plants in a sample area will not be in bloom, this technique is more helpful for year-round plant identification. As each plant is keyed-out, users will uncover interesting information about the plant, such as whether it is native or an exotic introduction. If the plant is exotic, reasons are given about why it is a threat to native species.

Bridging the Watershed Activities: A Constructivist Approach

It sounds like a simple proposition: we construct our own understandings of the world in which we live. We search for tools to help us understand our experiences. To do so is human nature. Our experiences lead us to conclude that some people are generous and other people are cheap of spirit, that representational government either works or doesn't, that fire burns us if we get too close, that rubber balls usually bounce, that most people enjoy compliments, and that cubes have six sides. These are some of the hundreds of thousands of understandings, some more complex than others, that we construct through reflection upon our interactions with objects and ideas.

Each of us makes sense of our world by synthesizing new experiences into what we have previously come to understand. Often, we encounter an object, an idea, a relationship, or a phenomenon that doesn't quite make sense to us. When confronted with such initially discrepant data or perceptions, we either interpret what we see to conform to our present set of rules for explaining and ordering our world, or we generate a new set of rules that better accounts for what we perceive to be occurring. Either way, our perceptions and rules are constantly engaged in a grand dance that shapes our understanding.

Consider, for example, a young girl whose only experiences with water have been in a bathtub and a swimming pool. She experiences water as calm, moving only in response to the movements she makes. Now think of this same child's first encounter with an ocean beach. She experiences the waves swelling and crashing onto the shore, whitecaps appearing then suddenly vanishing, and the ocean itself rolling and pitching in a regular rhythm. When some of the water seeps into her mouth, the taste is entirely different from her prior experiences with the taste of water. She is confronted with a different experience of water, one that does not conform to her prior understanding. She must either actively construct a different understanding of water to accommodate her new experiences or ignore the new information and retain her original understanding. This, according to Piaget and Inhelder (1971), occurs because knowledge comes neither from the subject nor from the object, but from the unity of the two. In this instance, the interactions of the child with the water, and the child's reflections on those interactions, will in all likelihood lead to structural changes in the way she thinks about water…

As human beings, we experience various aspects of the world, such as the beach, at different periods of development, and are thus able to construct more complex understandings. The young child in this example now knows that the taste of seawater is unpleasant. As she grows, she might understand that it tastes salty. As a teenager, she might understand the chemical concept of salinity. At some point in her development, she might examine how salt solutions conduct electricity or how the power of the tides can be harnessed as a source of usable energy. Each of these understandings will result from increased complexity in her thinking. Each new construction will depend upon her cognitive abilities to accommodate discrepant data and perceptions and her fund of experiences at the time.

—Excerpted from The Case for Constructivist Classrooms
by Jacqueline Brooks and Martin Brooks

The activities in this module use a constructivist, interdisciplinary approach. Students construct their own knowledge of the science underlying the problems/issues they explore. Activities include lively discussions, writing, research, and the use of the scientific method to observe and gather authentic data. Students observe problems in the watershed in which they live from a historical perspective, from the perspective of being a member of the human community, and from the perspective of an environmental scientist. Working in

cooperative groups, and at times individually, students participate in activities that include engaging questions and situations. They are guided through field and laboratory explorations that invite them to hypothesize about what will happen, to interact with natural phenomena, to observe, and to collect data about their observations. They will test their theories, explain results, and decide whether to keep, abandon, or modify their theories.

The teacher's role is to help students express their preconceptions about the problems and ideas presented in this module. After conducting the hands-on investigations, students are provided with opportunities to modify any misconceptions. Data collection combined with class discussions about alternative theories will provide motivation for further exploration and will help students restructure their knowledge base. In the process, students gain confidence in their abilities to learn and understand science as well as to gather useful scientific data about the watershed in which they live.

Several different models of instruction can help create a constructivist approach to learning. One model is based on the 5 E's (Engage, Explore, Explain, Elaborate, Evaluate), an instructional model in five phases. The phases, explained on the next page, form the structure around which the activities and procedures are organized.

ENGAGEMENT

This phase is designed to grab the student's interest. An object, situation, or problem that relates to the student's world is presented with an authentic question, a problem description, or an interactive scenario. The engagement is meant to lead the student to the upcoming task. The role of the teacher in this phase is to present the situation or problem and to identify the task. If this phase is successful, students are motivated to continue to the next phase: the exploration.

EXPLORATION

Exploration activities are meant to provide students with concrete experiences which they can build upon as they discover new concepts and learn new processes and skills. These activities bring answers and, if successful, satisfaction to the student. During the exploration phase, students need time to explore objects, events, or situations. They gather data to help them establish relationships, construct mental pictures, observe patterns, and question preconceptions. The teacher facilitates the exploration and coaches students from the sidelines. The teacher answers students' questions and helps them to begin restructuring their knowledge. At the end of this phase, students should be prepared to explain what they have discovered.

EXPLANATION

This is the phase in which students should "see the light." The concepts, processes, and skills to which they have been exposed become clear. The learning is internalized. During the explanation phase, students and teachers agree on appropriate vocabulary to discuss the discoveries students have made. The teacher's role is to ask students to summarize what has happened in their own words. Then the teacher begins to introduce scientific terms to describe the results. Explanation often provides order to the earlier phases and should lead quickly to the ability to elaborate on what has been learned.

ELABORATION

This phase is designed to provide students with a chance to take what they have learned and extend or apply the concepts, processes, or skills to their lives. Often, elaboration activities are interdisciplinary and may involve writing, mathematics, or social studies. When students can clearly connect the early explorations with the explanations and the concepts with the observations, learning has been internalized. They are ready to evaluate their work.

EVALUATION

Students need to receive feedback on whether their explanations have been adequate. Informal evaluations occur all during the learning task, but a more formal evaluation should occur after the elaboration phase. Students should evaluate their own work and understanding, as well as be evaluated by the teacher. Authentic assessment techniques can be employed to give students meaningful feedback.

ADDRESSING THE NATIONAL AND LOCAL CURRICULUM STANDARDS

Educational reform and the drafting of national education standards in many of the disciplines for curriculum development, assessment, and teaching have had a major impact on educators. National standards are not meant to suggest a "national curriculum" but to guide local- and state-level curriculum developers in raising the expectations in classrooms across the country. The modules presented as part of the Bridging the Watershed program address many of the standards developed across disciplines.

Please see the AFF website for current local and state standards.

MODULE ORGANIZER

TITLE	GOAL(S)	MATERIALS LIST
Crumpled Paper Watershed	To understand how surface water flow is determined by the shape of the land.	• 2 pieces of plain scrap paper (8.5 X 11) • Spray bottle • Water • Water-based markers (blue, brown, and black)
Close to Home: Your Local Watershed	To identify your local watershed.	• Internet access
Who Polluted the Potomac?	• To become aware of the many different ways pollutants can enter a river. • To realize that protecting the environment is not a one-time action, but that it requires ongoing changes in our daily habits.	• 1 gallon tap water in a clear container • 16 labeled film canisters or other small containers • Dry clay soil • Crumbled dry leaves • Vegetable oil • Assorted litter (pull tabs, Styrofoam, etc.) • Nylon fishing line • Potassium chloride or ¼ tsp. baking powder • Molasses, coffee or food color mix • Yellow food color mixed in water • Toilet paper • Vinegar • Monosodium phosphate or baking soda • Blue/green food color mixed in water • Soapy water • Red food color mixed in water
Potomac River Watershed Timeline	To construct a timeline showing how land use change and a growing population has impacted the waterways in the the last 400 years.	• Colored markers •1-meter paper strip (receipt tape works well) • Meter stick
A Lengthening Growing Season	To graph frost dates from a weather station along the Potomac to see how the growing season has increased in the past century.	• Frost dates • Computer for graphing • Formula for frost dates
Gorgeous Gorge Game	To understand the importance of "leave no trace" ethic particularly as it applies to "frontcountry" or day-use parks.	• Gorgeous Gorge Game • Playing pieces • Instructions for playing the game
RESOURCES		
Climate Change Impacts Along the Potomac	To understand climate change and how it will impact the Potomac River watershed.	• Reading assignment

Crumpled Paper Watershed

OVERVIEW:

Students will a create a model of a watershed. By observing how surface water flow is determined by the shape of the land, students will visually and dramatically observe the physical characteristics of a watershed, and investigate the impacts of human land-use decisions. Students should have an understanding of the water cycle before this activity.

BACKGROUND INFORMATION:

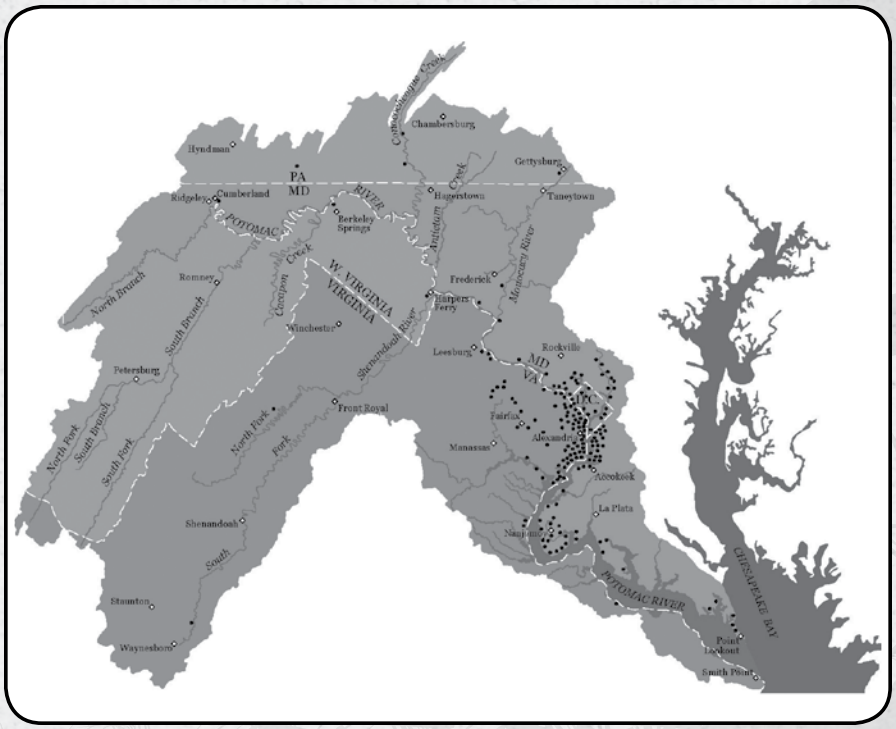
What is a watershed?

A watershed is all of the land that drains runoff (from precipitation) into a body of water, such as a creek, river, lake, bay or ocean. The boundary of a watershed is the ridgeline of high land surrounding it, like the edge of a bowl. Another term for watershed is "drainage basin."

As rainwater and snowmelt run downhill, they carry whatever is on the land, such as oil dripping from cars, trash and debris on streets, or exposed soil from construction or farming, to the nearest water body.

Our Local Watershed

Everyone lives, works and plays on land that drains into a body of water, like a creek or river. Our local watershed may lead to a tiny creek, but that eventually drains into a river, bay, or ocean.



Goal:

To understand how surface water flow is determined by the lay of the land.

Materials List:

Provide the following materials per group or individual

- 2 pieces of plain scrap paper (8.5 X 11)
- Spray bottle
- Water
- Water-based markers (blue, brown, and black)

New Terms and Topics:

- Watershed
- Runoff
- Landforms
- Pollution
- Land use
- Ridge
- Water cycle

Crumpled Paper Watershed

We live in the Potomac River watershed, which includes parts of Maryland, Virginia, Pennsylvania, West Virginia, and all of Washington, D.C. The Potomac River watershed is part of the larger Chesapeake Bay watershed.

PROCEDURE:

1. **Have students clear their desks, since their desks will get wet during the activity.**

2. **Ask, "What Happens to rainwater after it falls? Where does it go?"**
   Some answers will include the concept that some rain goes into the ground and some runs downhill.

3. **Pass out Student Sheets – Crumpled Paper Watershed, one sheet of 8.5" x 11" paper, and markers.**

4. **This activity can be conducted in two different ways, as detailed:**
   - **Teacher-directed:** You can work through the instructions on the Student Sheets as a class, giving instructions orally and demonstrating the steps as necessary, or
   - **Self-directed:** Students can read and follow the instructions on the Student Sheets at their own pace, with you monitoring student progress throughout the activity and giving assistance where necessary.

5. **Discuss student results and answers to the questions in the "Analyze Your Data and Draw Conclusions" section of the Student Sheets.**

6. **Ask students to create models of a watershed using other materials such as modeling clay or aluminum foil.**

7. **Use completed Student Sheets for evaluation.**

Crumpled Paper Watershed

STUDENT SHEET: CRUMPLED PAPER WATERSHED

Set Up Experiment #1	Follow the instructions below to set up the experiment. 1. Crumple up the piece of paper your teacher gave you, and then smooth it back out most of the way. It should still be a bit crumpled, showing small ridges (high points) and valleys (low points). 2. Imagine that this paper is a section of land, and find the ridgelines (the tops of the fold-lines). 3. Use a washable blue marker (not permanent) to color along the ridgelines on your "land."
Make Your Hypotheses	You are going to "rain" on your landform. Answer the following questions to make your hypotheses before conducting the experiment. 1. What do you think will happen to your land when it "rains?" 2. What will happen to the blue ridgelines you colored? 3. Where will the "rainwater" travel?
Run the Experiment	Follow the directions below to conduct the experiment. 1. Use a spray bottle of water to create a "rainstorm" over your land. You want to create gentle sprays of mist. 2. Observe what happens after every misting. 3. As your "rainfall" accumulates, observe the pathways where the excess "rainfall" travels.

Crumpled Paper Watershed

Record Your Observations	In the space below, record your observations about what happened. Use words and pictures if you wish.
Analyze Your Data and Draw Conclusions	Answer the following questions or complete the activities to analyze and draw conclusions about your data. a. Explain how your hypotheses were or were not accurate. b. How did the "rainfall" travel over your land? c. Where did the water collect? Explain why this happened. d. Find an area on your land where water collected. This is a lake, and you get to name it! My lake is Lake _____. e. Look for the major stream running into your lake. Name this stream as well. My stream is called _____.

Crumpled Paper Watershed

Analyze Your Data and Draw Conclusions	f. This stream may have several tributaries (small streams which run into the larger stream). How many does your stream have? _____ g. With your finger, trace your stream all the way back up to where it starts at the top of the ridge. (This should be a path of blue ink.) When you reach the top, this is the edge of the watershed for your stream and lake. h. Trace the entire edge of the watershed with your finger by following the ridgeline. This will be something like tracing the edge of a bowl. All of the inside, downward-sloping area you have just outlined is the watershed for your stream and lake. i. Draw a picture of your watershed below. Label your stream and lake. j. How many other watersheds can you find on your "land?" _____ k. How would you define the word "watershed?"

Crumpled Paper Watershed

EXPERIMENT #2

Set Up Experiment #2

Follow the instructions below to set up the second experiment.

1. On a fresh sheet of paper, draw some of the ways people use the land. Include a house/community, farm, factory, and some streets/highways.

2. Using the color key below, color your areas with markers.

Color	Represents	What might be on this land that you wouldn't want in the water?
Brown	Farms	
Red	Landfills & Factories	
Black	Houses & Streets	

3. Crumple this paper, and smooth it in the same way you did the first one.

4. Use the blue marker to trace the ridgelines on this paper.

Make Your Hypotheses

Make hypotheses about what you think will happen when you "rain" on your land this time.

Run the Experiment

Gently mist your new land with water from your spray bottle. Observe what happens, and how the water travels.

Record Your Observations

Record your observations (in words and pictures) here.

Crumpled Paper Watershed

EXPERIMENT #2

Analyze the Data and Draw Conclusions	Answer the following questions to analyze and draw conclusions about your data. 1. What happened in your second experiment? 2. What do you think the colors could represent in real life? • Brown = _____ • Red = _____ • Black = _____ 3. Where were the colors in the end? 4. Where are you in this watershed? What kinds of pollution do you think you add to the watershed?

Crumpled Paper Watershed

EXPERIMENT #2

Checking For Understanding	Circle the letter of the correct answer for each of the following questions to show you understand the information in this activity. 1. Choose the best description for the watershed of a stream: a. the water of a stream and all the tributaries that feed into it, including wetlands b. all the land that slopes toward the stream and drains rain and melting snow into the stream c. a large wet area of land that completely surrounds the stream. 2. You are hiking along a trail in a hilly countryside. You know that you have reached the watershed of a different stream because: a. the ground changes from soggy soil to dry forest b. you can see another stream c. you are standing on a high spot and the land starts to slope downward again.

Close to Home: Your Local Watershed

BACKGROUND INFORMATION:

Freshwater resources are essential to humans, other animals, and plants. The metropolitan Washington, D.C. area draws most of the water for human use from the Potomac River. At the same time, the Potomac is also used to carry away wastewater. The Potomac River is part of the Potomac River watershed, which in turn is part of the larger Chesapeake Bay watershed. The Environmental Protection Agency (EPA) maintains a listing of watersheds in the United States, water quality monitoring data from the watershed, and citizen-based groups at work in the watersheds.

In this activity, students will use the EPA to identify and investigate the health of the watersheds in which they live and attend school.

PROCEDURE:

1. Log onto the EPA web site at http://cfpub.epa.gov/surf/locate/index.cfm.

2. Scroll down to "Locate by geographic unit." Select "zip code (5 digit number)," type in your local postal Zip Code, and click "submit." Record in Table I: Local Watershed Information the 8-digit United States Geological Survey (USGS) Cataloging Code.

Goal:

To identify and investigate the health of your local watersheds.

Class Time:

30 minutes

Group Size:

Students can work individually or in groups of 2-3.

Materials List for Every 2 Students:

Internet access

Special Considerations:

- If access to the Internet is not readily available, the information can be printed out in advance from the web site to be used in class to complete the activity.
- A map showing the Potomac River watershed, Chesapeake Bay watershed and your school location will help orient students.

Close to Home: Your Local Watershed

TABLE 1: LOCAL WATERSHED INFORMATION (WASHINGTON, D.C. METRO AREA)

	Name of Watershed	USGS Cataloging Code
Home	The likely answers in the Potomac Watershed are: • Middle Potomac-Anacostia-Occoquan • Lower Potomac • Patuxent • Middle Potomac-Catoctin	8 – digit codes vary with watershed names. The most likely answers for zip codes in the Washington, D.C. metropolitan area are: 02070010 02070011 02060006 02070008
School		

Students can further explore the EPA website to supplement their knowledge of their local stream or the stream in the chosen national park field study site.

1. **Scroll down to "Citizen-based Groups at work in this watershed," and click the link. Have students choose five groups and fill out the information for each in table 2.**

Table 2: Citizen-Based Groups at Work in This Watershed

Group Name	Area Of Monitoring	# Of Volunteers	Website?
Alliance for the Chesapeake Bay	Pennsylvania, Maryland, Virginia	125	Yes

2. **Scroll down to "Assessments of Watershed Health," and click on the link "Impaired Water for this Watershed." Choose a state (D.C., MD, or VA) and click the link. When the new page loads, scroll down and locate the chart titled "Causes of Impairment for Reporting Year 2010: Virginia, Middle Potomac-Anacostia-Occoquan." Choose five water bodies and list the cause of impairment for each in table 3.**

Table 3: Causes of Impairment of Watershed

Name Of Watershed	State Report	Water Body Name	Cause Of Impairment
Middle Potomac-Anacostia-Occoquan	VA	Accotink Creek	Benthic macroinvertebrate bioassessments

3. **Students can further explore the cause of impairment by clicking on the box titled, "Frequent Questions," on the right-hand side of the screen. Scroll down to and click on "Assessing Water Quality (Questions and Answers)."**

Who Polluted the Potomac?

BACKGROUND INFORMATION:

You will read aloud an interactive story dramatizing how population growth and changes in land use can cause a river to become so polluted that it is transformed from a valuable resource into a repugnant and even toxic wastewater. The emphasis in this activity is on nonpoint source pollution, which originates from sources that are not easy to identify. Nonpoint source pollution is mostly the result of runoff and includes fertilizers and other toxic chemicals washing off lawns and farmland; oil, grease, and litter from streets and parking lots; soil eroding off construction sites; and air pollutants washed to earth by rain. These pollutants are very difficult to measure and control, and they have a great impact on life in a water body.

This exercise demonstrates that we are all part of the problem. It also shows that protecting the environment is not a one-time event, but requires ongoing changes in our daily habits. After completing this activity, students should be ready to discuss the actions they can take to help prevent pollution.

Fill the 16 canisters as indicated in the following chart:

"Factor"	Substance in Canister
Construction site	3mL dry clay soil
Trees	Dry leaves, crumbled
Motorboat	1mL vegetable oil
Beach party	Assorted litter (pull tabs, Styrofoam, etc.)
Family picnic	Assorted litter (paper, plastic wrap)
People fishing	Tangle of nylon fishing line
Farmer	Potassium chloride or 2mL baking powder
Barnyard	Molasses, coffee, or food color mix
Homeowner	Yellow food color, water, and toilet paper
Coal mine	1/4 canister of vinegar
Electric power plant	1/4 canister of vinegar

(Chart continued on next page.)

Goal:

- To become aware of the many different ways pollutants can enter a river.
- To realize that protecting the environment is not a one-time action, but that it requires ongoing changes in our daily habits.

Materials List:

- Water quality testing kits for each parameter
- 1 gallon of tap water in a clear, colorless, wide-mouthed container
- 16 labels (found on page 14)
- 16 film canisters or other small containers (one for each factor)

Suggested Adaptation

- Teachers with water-quality testing kits and labs can test the water before and after the story for apparent color, odor, pH, orthophosphates, nitrates and turbidity using the techniques from "Understanding the Water Quality Index" exploration activity in the Watershed Watchdogs module.

Who Polluted the Potomac?

PROCEDURE:

1. Before class begins, make a copy of the following labels on page 14. Cut them out and tape them to film canisters. Fill the canisters with the ingredients listed on pages 12-13. Put one gallon of tap water into the container to represent the Potomac River.

"Factor"	Substance in Canister
Commuters	¼ canister of vinegar
Gardeners	2mL monosodium phosphate or baking soda
Antifreeze	Blue/green food color and water
Washing the car	½ canister of soapy water
Mysterious liquid	1mL diluted red food color and water

Note: The canisters need to be labeled and filled before the class begins.

2. Have students arrange themselves around the container of water that represents the "Potomac River."

3. Distribute a set of canisters to the students representing the factors that impact a waterway. Students should keep the identity of the factor/contents of their canister a secret. Explain that when a factor is mentioned as you read the story (below), the student with the corresponding canister should empty the contents into the "river" (the jar of water).

4. Read the following story out loud to the class.

THE STORY OF "WHO POLLUTED THE POTOMAC?"

For many thousands of years, people have lived on the banks of the Potomac River. They hunted in the great forests, harvested food from the wetlands, and fished the river.

Imagine that the jar of water was taken from this river about 500 years ago.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

In 1608, Captain John Smith explored the Potomac for settlement by European colonists. He kept a journal of his discoveries, writing about the Native American villages, the forests, and the river itself. He described tributaries of "sweet waters" and the river so full of fish that he and his crew tried to scoop them up with a frying pan.

Soon colonists began to arrive. They found fertile land for farming, forests teeming with game, and a river that provided ample food and water. It was an outstanding environment for settlement, and the colonists prospered.

Who Polluted the Potomac?

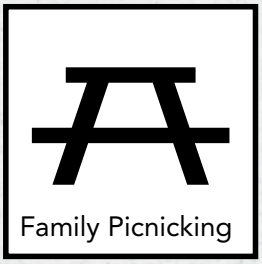
CANNISTER LABELS

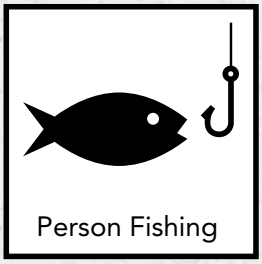

Trees


Construction Site

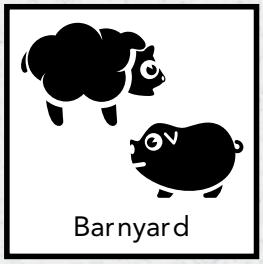

Motorboats


Beach Party


Family Picnicking

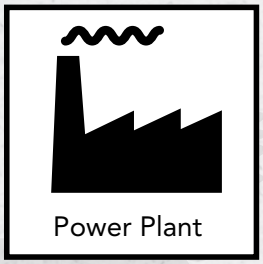

Person Fishing


Farm


Barnyard


Homeowner


Coal Mining


Power Plant


Commuters


Gardeners

Antifreeze


Washing the Car


Mysterious Liquid

The Potomac River has changed a lot in the past 400 years. This is the story of the changes.

Listen for the name of the character printed on your canister. When you hear your character named, open the canister and dump its contents into the river.

Imagine now that everything in the story is happening in the present – maybe even while we're sitting here today.

Who Polluted the Potomac?

A sudden downpour drenches the area. The pounding rain is washing loose soil from a nearby **CONSTRUCTION SITE** into the river. High winds whip through the **TREES** and blow leaves into the water.

Imagine that the jar of water was taken from this just after a downpour.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

In a short while, the storm passes over and the sun comes out again. People head for the river to have fun. Some zoom up and down the river in **MOTORBOATS** and don't notice that a little engine oil leaks into the water.

A group of friends have spread blankets on the shore for a **BEACH PARTY**. Lots of families are **PICNICKING** in the parks, too. Some of these people have left trash on the shore. At the next high tide, or during the next rain, that trash will wash into the river. On the dock, a **PERSON FISHING** snags the hook on a log and breaks the nylon fishing line.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Not everyone is out playing today. A **FARMER** has been fertilizing cornfields close to the shore. The rain washed some of the fertilizer off the land and into the nearby river. The farmer also keeps pigs and other animals in the **BARNYARD**. As the rainwater drains out of the barnyard, it carries some of the manure into a little creek behind the farm. The creek flows into the river.

Out in the country, high on a hill overlooking the river, is an old house. It is not connected to the city sewer system. Wastewater from the house goes into a septic tank underground. The **HOMEOWNER** has not maintained the septic tank, and poorly treated sewage is seeping into the river.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Who Polluted the Potomac?

Upstream is a **COAL MINE**. Rainwater drained down into the shaft and soaked the piles of wastes and scraps from mining. This made the water become acidic – like strong vinegar. Then the acid water trickled back out into the river.

The **ELECTRIC POWER PLANT** on the river burns coal to produce electricity. The gases coming out of the smokestacks combine with moisture in the air to form acids. The pollution falls back to Earth as acid rain or snow.

Many **COMMUTERS** drive their cars to and from work. Car exhaust fumes (just like the power plant fumes) cause more acid rain. If a car is not kept in good repair, it might also leak oil or other fluids, which will be washed off the pavement and into the river with the next rain.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Let's look in on some typical activities around the neighborhood. Lots of **GARDENERS** are out working in their yards today. Many of them are using weed killers and insect sprays to keep their lawns pretty. The next rainfall will wash these poisons into a little creek nearby, and then into the river.

There's a father teaching his daughter how to change the antifreeze in her truck. They pour out the used **ANTIFREEZE** on the driveway. Antifreeze is sweet-tasting and can poison an animal that licks it. It can also get into the nearby creek and poison fish.

Later, father and daughter **WASH THE CAR**. The soapy water rushes down the driveway into the storm drain; the storm drain empties into the river. Phosphates in detergents used to be a pollution problem because they acted like fertilizer, making too much algae grow in the river. Laws were passed to stop the use of phosphate soaps in order to help solve the algae problems. But the grease and grime on a car contain asphalt from the roads, asbestos from the brakes, rubber particles from the tires, heavy metals, and rust. If the man and his daughter had gone to the local car wash, the water would have been treated before it was returned to the river.

Next door a family is cleaning out their garage. They find an old rusty can with a tattered skull and crossbones label still stuck on it. What could it be? It looks dangerous, and they want to get rid of it before someone gets hurt. But how? One of the kids gets the idea: "Let's pour it down the drain out by the curb. Hurry up! " So the **MYSTERIOUS LIQUID** goes down the storm drain. The poison is out of sight, but it is headed for the river.

Imagine that the jar of water was taken from this river now.

Would you drink this water?

Would you swim in it?

Would you go boating in it?

Is it safe for wildlife?

Why or why not?

Who Polluted the Potomac?

Who polluted the Potomac?

After you have completed the story, test the water again for apparent color, odor, pH, orthophosphates, nitrates and turbidity. Use the following questions to stimulate class discussion.

Think about what was in the canisters:

1. **Could something be done to prevent that type of pollution from entering the river?**
2. **What could you start doing right away to help improve the health of the watershed where you live?**
3. **What do you think would have to be done to this water to make it safe to drink?**
4. **Once pollutants have entered the river, how can we get them out?**
5. **How can we clean up the river?**
6. **Do you think it is easier to prevent pollution or clean it up?**

Potomac River Watershed Timeline

BACKGROUND INFORMATION:

Four hundred years ago, significantly fewer humans lived in and around the Washington, D.C. area. When the number of people inhabiting an area increases, it changes the land and the waters of the region. A timeline is one way to illustrate the changes that have occurred over time.

Land use in the Washington area over the last 400 years has been increasingly urbanized. Agricultural land and forests have been replaced by homes, schools, businesses, and roads. Much of the open land has been covered with impervious surfaces (roads, sidewalks, buildings, parking lots). Humans have deliberately altered bodies of water to enhance the living environment or to facilitate commerce. Erosion and sediment deposition have also altered bodies of water.

Human activities have greatly accelerated natural processes and created a myriad of pollution problems. Once the problems exist, they must be recognized, and steps must be taken to correct them. However, it is important for students to understand that environmental problems cannot be corrected quickly and to recognize when improvements have occured. In this activity, students will explore the changes in the Potomac River watershed over the last 400 years and the impact of humans on the river and its tributaries.

PREPARATION:

Cut a paper strip 1 meter long for each group of 2 students.

PROCEDURE, QUESTIONS, AND POSSIBLE RESPONSES:

1. **How old is your school?**

2. **How old is the building in which you live?**

3. **How old is the local shopping mall?**

   Answers will vary, but in most cases, students' homes, schools, and many buildings in their communities did not exist 50 years ago.

4. **Imagine your community 50 years ago. Make a list of things you could find today that were there 50 years ago.**

   The bodies of water themselves, certain older buildings, some bridges, some trees, and natural formations like caves are the kinds of things students should recognize as having been present 50 or more years ago.

Goal:

To construct a timeline showing how land use change and a growing population have affected the waterways in the Potomac River watershed over the last 400 years.

Class Time:

45 minutes

Group Size:

Groups of 2 students

Materials List for Each Group:

- Colored markers
- 1-meter paper strip (receipt tape works well)
- Meter stick

Special Considerations:

This is an open-ended activity requiring critical thinking. The students' timelines will vary. Students should be able to justify their choices and explain why each date fits each category. Students need to be able to find the Chesapeake Bay, the Potomac River, and the Anacostia River on a map.

New Terms and Topics Introduced in this Activity:

Sedimentation

Potomac River Watershed Timeline

5. **Draw a vertical line across one end of the paper strip. Label this line "1600."**

6. **One centimeter represents 5 years, and 2 centimeters represent a decade or 10 years.**

7. **Using this scale, start at the 1600 line and draw a line for each decade from 1600 to the present.**

8. **Read carefully the "History and Water Quality of the Potomac River Watershed" in the student pages.**

9. **Using a different color for each issue, draw a horizontal line on your 1-meter paper strip, beginning when each of these problems was first noted and continuing up to a date when the problem was solved:**
   - **Brown:** sedimentation (soil erosion)
   - **Blue:** sewage (bacterial contamination)
   - **Green:** cultural eutrophication (excess nutrients such as nitrogen or phosphorus)
   - **Red:** chemical pollution (such as acids from mining, or urban and industrial runoff)
   - **Purple:** trash and litter pollution

   Line for sedimentation should begin at 1750, sewage at 1810, eutrophication at 1932, chemical pollution at 1894, trash at 1950, thermal pollution at 1951. All lines should continue to present.

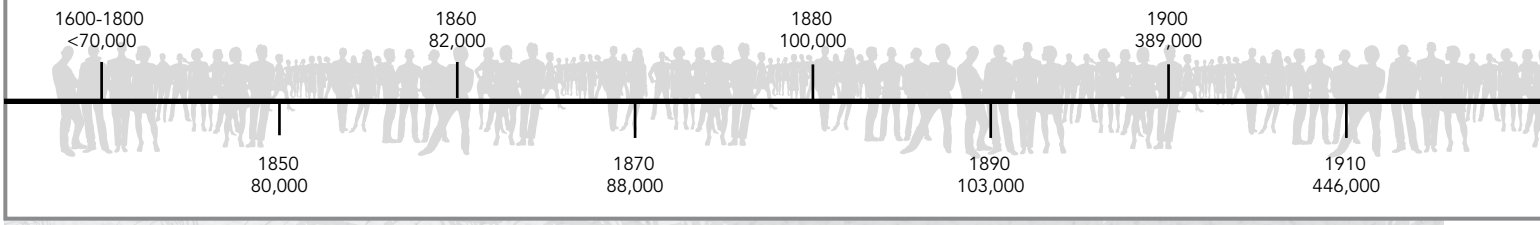
10. **On each colored line, draw an "X" at the year in which an attempt to address this problem was made. Using the same color, circle the date in the "History" that represents this "X."**

    Possible Responses:
    - Sediment problems begin in 1750. "X" at 1870 and 1970 as years of specific action to control sediment.
    - Sewage problems begin in 1810. "X" at 1938 (construction of Blue Plains), 1948, 1959 as years of action to address sewage problems.
    - Cultural eutrophication begins in 1932 (described as lower dissolved oxygen). "X" at 1976, 1985, and 2005 (refers to reduction of blue-green algae or excess nutrients).
    - Chemical pollution begins in the 1890s with the onset of the Industrial Revolution. "X" at 1945, 1948, 1977, and 1993.
    - Trash in the river begins in 1894. "X" at 1989, 2005, 2006, and 2010.

SUGGESTED ADAPTATIONS:

- Teachers may prepare the timeline in advance for their students or they may assign students a sub-section of the total timeline or just one of the pollutants.
- Some teachers work with History or Social Studies teachers to encourage students to connect these moments in time with other historical events and trends.

POPULATION OF WASHINGTON, D.C. METRO AREA



Potomac River Watershed Timeline

In addition to the above, many governmental or citizen actions have tried to address several, if not all, of these problems. An "X" may be placed on several lines for each of these years.

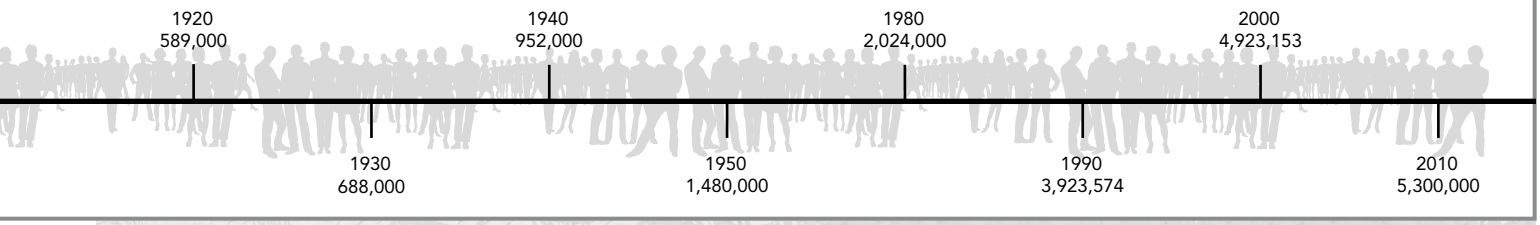
As students construct their timelines, they should come to realize that these problems are severe and ongoing. Students should be able to justify each decision, by referring to the History, as they draw their lines and mark their "X"s.

11. Which of these problems have been solved? Choose one of the problems to research and find out how severe this problem is today in the Potomac River. Try using current newspaper or magazine articles, or searching on the Internet.

None of these problems are completely solved, but many efforts have been and are being made to address them. In particular, federal legislation in the 1970s curtailed much point-source pollution; half the water bodies listed as impaired then have since been declared fishable and swimmable.

Suggested extensions for students:

- Start a bulletin board of current news articles relating to these problems.
- Assign individuals or small groups to research the details of a government action, such as the Maryland Water Quality Improvement Act of 1998.
- Assign individuals or small groups to learn about a citizen action group, and what members of the group do to preserve or protect the watershed.
- Ask students to look around their home neighborhoods to try to identify sources of any of these problems, such as silt fences around a new construction site that let sedimentation through, or trash on the street that will wash into the river through storm sewers.



Potomac River Watershed Timeline

POTOMAC TIMELINE[1]

This timeline represents an abbreviated history of water quality in the Potomac watershed (an area that stretches across parts of Maryland, Pennsylvania, Virginia and West Virginia as well as the District of Columbia).

Pre-1600 Native Americans hunt, fish, trap and plant their crops on small plots of land cleared by burning brush and trees. Large areas of forest surround their plots of land, buffering runoff into rivers even after severe rainstorms.

1608 Captain John Smith - the first European settler to fully explore the Chesapeake Bay and its tributaries - describes the Potomac as "… frequented by otters, beavers, martens, and sables. Neither better fish, more plenty, nor more variety for small fish had any of us ever seen in a place…".

1634 First Maryland colonists land near the mouth of the Potomac River. By the late 1600s, Prince George's County's 1,700 residents live primarily near streams. Less than two percent of the land is used for agriculture - primarily tobacco. Most of the land is still forest or meadow, resulting in little runoff or sediment.

1710 Colonists in Virginia commonly bury their trash. Holes are filled with building debris, broken glass, ceramics, oyster shells, animal bones and suits of armor.

1750 New towns are established downstream on Potomac as extensive logging, clearing of land for agiculture and housing, and more soil-destructive farming systems clog waterways with debris and sediment, making navigation further upstream impossible.

1810 The first sewer system in Washington, D.C. carries waste to the nearest stream.

1870 The Army Corps of Engineers dredges the Potomac River to keep it navigable.

1880s Industrial revolution ushers in intense pollution of skies and waterways. Factory smoke darkens the sky. Sediment and sewage flow into the water. Industrial waste and human and animal waste become a huge problem.

1890 Rock Creek Park created. Conservationist John Muir starts Sierra Club in 1892.

1894 United States Public Health Service reports "... at certain times of the year the [Potomac] river is so loaded with sediments as to be unfit for bathing as well as for drinking and cooking purposes. It contains fecal bacilli at all times." Disgusted by the sight of barge loads of garbage floating down the Potomac River from Washington, D.C., citizens of Alexandria, VA sink the barges.

1 "Potomac Timeline." Interstate Commission on the Potomac River Basin. Web. 20 Sept. 2010. www.potomacriver.org/cms/index.php?option=com_content&view=article&id=96&catid=39&Itemid=57. Also, "Bay History – About the Bay – Chesapeake Bay Program." Chesapeake Bay Program — A Watershed Partnership. 23 Dec. 2009. Web. 20 Sept. 2010. www.chesapeakebay.net/history.html.

Potomac River Watershed Timeline

1902 President Theodore Roosevelt focuses national attention on protection of the nation's water and forest resources in his first State of the Union address.

1930 Washington Suburban Sanitary Commission (WSSC, Prince George's and Montgomery counties) connects its sewer system to DC's.

1932 Untreated wastes from Metro area population of 575,000 flow into Potomac. Heavy bacterial contamination forces river closing for swimming for 13 miles in lower Potomac. Low dissolved oxygen levels also endanger fisheries.

1938 Blue Plains wastewater treatment plant in Washington DC is completed, with a capacity of 130 million gallons per day (mgd) primary treatment (heavy solids settle; lighter solids float to the surface and are discharged or subjected to secondary treatment).

photo: Courtesy of DC Water.

1940 The Interstate Commission on the Potomac River Basin (ICPRB) is created to protect the Potomac River watershed.

1945 PA passes the nation's first law to place limits on acid-mine drainage pollution to streams.

1948 Congress enacts the first Federal Water Pollution Control Act, a 5-year plan to award grants to states to control pollution and build sewage treatment centers. The Act is extended and strengthened several times over the next decade.

Shenandoah River below Front Royal termed a "biological desert" due to industrial wastes.

1950 Post-World War II prosperity leads to increased spending by Americans, especially in consumer goods. Disposable containers are widely used.

1951 Low dissolved oxygen levels kill thousands of fish during the summer. Local media call attention to the Potomac's poor condition, describing it as "an open sewer." Wastes from raw and partially treated sewage of Washington, DC's population is double that of 1932.

1956 Several citizen watershed groups established.

1957 Public Health Service declares Potomac River unsafe for swimming. On average, 60 million cubic feet of sediment is deposited annually within the metropolitan DC section of the Potomac.

1959 Secondary treatment of waste water added at Blue Plains.

Potomac River Watershed Timeline

1960 Work begins on a plan to separate DC's combined sanitary and storm water sewers. Treatment plant in Westernport, MD, begins operation to clean up pollution in the North Branch Potomac.

1964 Several VA and MD suburban counties' sewage tied into DC's Blue Plains.

1965 Congress passes The Water Quality Act of 1965, establishing a Federal Water Pollution Control Agency and requiring water quality standards. President Lyndon B. Johnson labels the Potomac "a national disgrace," and sets clean–up goals.

1966 The Clean Water Restoration Act passes, increasing grants for research, state programs, and construction of wastewater treatment plants.

1970 The US Environmental Protection Agency (EPA) is established. Several jurisdictions pass erosion and sediment control laws.

1971 Water contact sports in the Potomac, Rock Creek, and the Anacostia River prohibited. Urban sediment is a major concern.

1972 The Federal Water Pollution Control Act Amendments initiate ground-breaking changes in water pollution control programs with a national goal of "swimmable-fishable" waters. The Act is later amended as the Clean Water Act in 1977 and 1987.

1976 The Resource Conservation and Recovery Act takes effect to deal comprehensively with solid waste issues.

There is a noticeable lack of blue-green algae mats that had covered the upper estuary a decade earlier. Pleasure boaters rediscover the Potomac; largemouth bass reappear.

1977 Congress passes Federal Surface Mining Control & Reclamation Act.

Clean Water Act strengthened to control toxic pollutants and to allow states to assume more regulatory responsibilities.

Mercury is discovered in sediments and fish in the Shenandoah River.

1980 Federal Superfund legislation takes effect, marking beginning of national effort to clean up abandoned hazardous waste sites.

1983 EPA completes its Chesapeake Bay Study. Several jurisdictions sign Chesapeake Bay Agreement calling for unified effort to improve the health of the Bay.

1985 MD initiates a phosphate ban and a fishing moratorium on fishing for striped bass.

Potomac River Watershed Timeline

1986 All major wastewater treatment plants in DC metro area achieve phosphorus removal. DC initiates a phosphate detergent ban.

Avtex Fibers – a rayon manufacturing plant on the Shenandoah River – is listed as an EPA Superfund site.

1987 Clean Water Act revised.

Multi-jurisdictional Anacostia Watershed Restoration Committee formed.

WV, MD agree to develop an acid-mine drainage abatement plan.

1989 Alice Ferguson Foundation starts first Potomac River Cleanup.

MD finds dioxin in North Branch fish. PCBs (polychlorinated biphenyls) are found in Shenandoah fish. PCBs and chlordane are found in DC fish.

1991 Anacostia River restoration action plan adopted.

1992 President George H.W. Bush declares 1992 the "Year of Clean Water."

1993 More than 400,000 gallons of diesel fuel from ruptured oil pipeline spills into a Northern Virginia tributary of the Potomac. Anacostia River deemed endangered and Anacostia considered a "region of concern" for chemical contaminants.

1997 WV initiates program to provide farmers with federal and state funds to implement water quality protection measures.

1998 Federal Clean Water Action Plan initiated; emphasizes watershed approach to restoring the nation's waters.

2002 Clean Water Act turns 30 and President George W. Bush declares 2002 the "Year of Clean Water."

2005 VA limits amount of nitrogen and phosphorous that large wastewater treatment plants are allowed to discharge.

AFF Watershed cleanup yields 217 tons of trash from 309 cleanup sites. 5,875 volunteers collect an average of 75 pounds of trash per individual.

2006 Chesapeake Bay watershed population hits 16.6 million.

First Potomac Watershed Summit convenes stakeholders from around the region to find innovative solutions, beyond community cleanups, to achieve a Trash Free Potomac.

2009 President Barack Obama signs Executive Order calling on the federal government to lead the effort to control pollution and protect wildlife habitats in the Chesapeake Bay region.

Federal farm bill funding directed to the Chesapeake Bay region to finance agricultural conservation practices that reduce pollution from farms. Annapolis, Md., becomes the first jurisdiction in the Chesapeake Bay watershed to ban phosphorus in lawn fertilizer.

Potomac River Watershed Timeline

2010

Anacostia River Cleanup and Protection Act takes effect, implementing a 5-cent fee on disposable plastic and paper bags. Anacostia River becomes second river in the nation to get a Total Maximum Daily Load (TMDL) for trash. Referred to as a "pollution diet," TMDL sets minimum levels of trash that must be removed from the river.

Potomac River Watershed Cleanup grows to 575 sites, 425 partners, and nearly 15,000 volunteers. Trash collected per volunteer drops for first time in 21 years.

Potomac River shows reduced nutrients and improved water clarity as a direct result of restoration efforts.

A "Lengthening" Growing Season

BACKGROUND:

Timing is a matter of life and death in nature. **Phenology** is a word derived from the Greek words phainos, meaning "to appear, to come into view," and logos, meaning "to study." Phenology is 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, first flower, last flower, first ripe fruit, and leaf shedding, among others. Phenophases commonly observed in animals include molting, mating, egg-laying or birthing, fledging, emergence from hibernation, and migration.

Climate change, which has already begun to lengthen our growing season, has serious implications on a number of levels. The longer growing season means exotic invasive plants have more time to edge out less adaptable native species. It also has consequences for migratory birds, which begin their migration north in the spring and south in the fall based on light cues. If plant bloom is out of sequence with bird migration, some species might not find enough food to continue their migration. Another concern is if exotic invasive plant species out-compete native species, high fat and protein insects (like caterpillars) whose diets are species-specific, might not be able to survive in areas heavily populated by invasive plants.

What is the human impact of a hotter climate? People living in communities in low-lying areas, like river deltas, will be forced to relocate, an environmentally caused human migration. A study by the United Nations University, Columbia University, and CARE International shows the most vulnerable areas include African regions, Indian Ocean island states Tuvaku and the Maldives, as well as delta areas in Mexico, Bangladesh, Vietnam and Egypt. This study estimates that, by 2050, as many as 200–million people will be forced to migrate to higher ground.

According to a report on "Climate Change and Food Security," issued by the Food and Agricultural Organization of the United Nations in 2008, "Climate change will affect all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impacts will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. Agriculture-based livelihood systems that are already vulnerable to food insecurity face immediate risk of increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. People living on the coasts and floodplains, in mountains, arid climates, and the Arctic are most at risk.

Goal:

- To visualize the concept of phenology (plant and animal life cycles) by plotting frost dates.
- To understand how climate change will impact different species, including humans.

Materials (located with supplementary materials):

- Frost dates for Potomac River watershed weather station
- Chart for converting dates to days of the year, suitable for creating a scatter plot.
- Computer access

Class Size:

Groups of 2-3 students

New Terms and Topics:

Phenology

Time:

Class period

A "Lengthening" Growing Season

Crop yield (the amount of food produced on a given plot of land) will also be negatively affected by climate change. According to the US Environmental Protection Agency, "While food production may benefit from a warmer climate, the increased potential for droughts, floods and heat waves will pose challenges for farmers. Additionally, the enduring changes in climate, water supply, and soil moisture could make it less feasible to continue crop production in certain regions."

PROCEDURE:

In this activity, we will provide you with the fall's first frost dates and spring's last frost dates (indicators of the beginning and the end of the growing season) so students can chart the weather for the past 114 years and see what the climate trend is in the Potomac River watershed. The data was collected in Laurel, Maryland, but can be generalized throughout the watershed since, geographically speaking, the climate will be the same from the headwaters to tidal Potomac.

The data provided on the spreadsheets with your supplementary materials has pages providing the year and date of the fall first frost dates (1896-2010) and spring last frost dates for the same time period. Use the Month/Day spreadsheet to convert the date to the day of the year. Insert that on the frost date chart. For instance, the first spring date provided is 4/9. This becomes 99, for the 99th day of the year.

When you've finished both the spring and fall frost dates, the only information you will need to plot a trend line will be the year and the day of the year.

Start with the fall dates. Highlight the data under the year and day of the year. Click on the Excel chart option, and open the xy scatter plot. When the chart appears, the data points will be very close together. Open the y-axis and set the minimum on the scale at 265 and the maximum at 345. Click on the data points, go to "Chart" on the pull down menu, and choose "Add Trend line."

You can repeat the same process with the spring dates, but set the y-axis at 70 for the minimum and 130 for the maximum.

QUESTIONS FOR STUDENTS:

1. **How will longer, hotter weather impact humans?**

   Possible answers include: migration away from low-lying coastal areas, possible water shortages accompanying droughts, food shortages as a result of changing weather patterns, and pest infestations as a result of more favorable temperatures. Your students may want to do additional research. Resources and links to sites are provided on the AFF website.

2. **How might a longer growing season impact the plants and animals in the Potomac River watershed?**

   Possible answers include: spread of non-native invasive plants resulting in fewer native species, loss of species unable to adapt to both warmer weather and changes in precipitation patterns, loss of habitat as a result of higher water levels in the river and bay.

3. **What species will find it difficult to adapt to the warmer climate?**

   Possible answers include: benthic macroinvertebrates and amphibians. Some species, like marsh wrens and diamondback terrapins, which rely on coastal salt marshes, will have reduced habitat with sea level rise.

A "Lengthening" Growing Season

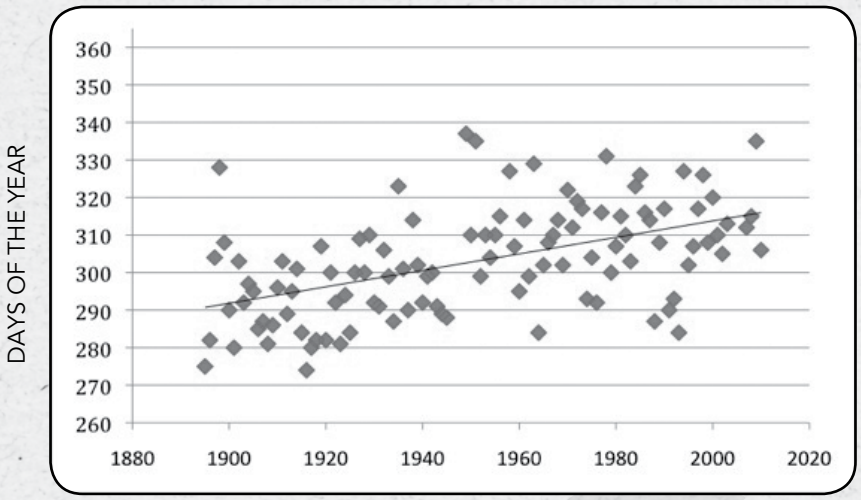
4. **How will climate change impact residents in the Potomac River watershed?**

   Possible answers include: more flooding in areas such as Alexandria (which currently experiences flooding); and more extreme weather, including stronger storms and possible tornadoes.

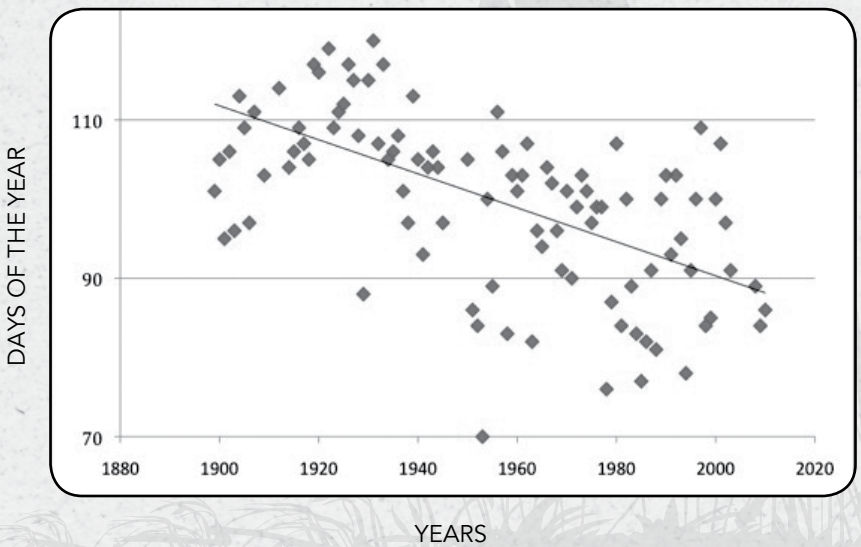
5. **How else might you apply this data? Is it possible to make some predictions about future climate from the data? Why or why not?**

   Additional phenology resources are on the AFF website.

FALL: FIRST FROST DATES



SPRING: LAST FROST DATES



Gorgeous Gorge Game

While this game is specific to the Potomac Gorge, the principles of Leave No Trace (LNT) are important to follow in any park. The full–size game, cards, and instructions can be downloaded and printed from http://fergusonfoundation.org/btw/potomacgorge.shtml

BACKGROUND INFORMATION:

Leave No Trace is a plan that helps people to be more concerned about their environment and to help them protect it for future generations. Leave No Trace applies in a backyard or local park (frontcountry) as much as it does in the wilderness (backcountry).

What is Leave No Trace? The best description comes from the Leave No Trace Center for Outdoor Ethics, an educational, non¬profit organization dedicated to the responsible enjoyment and active stewardship of the outdoors by all people worldwide:

"In an effort to address the explosive use of America's 'front¬country' or day-use areas, Leave No Trace Center for Outdoor Ethics has expanded its educational focus to include these sites. The Leave No Trace Frontcountry Program has been developed in cooperation with land managers and has experienced significant growth over the past few years.

Various demographic, geographic and behavioral factors have been taken into consideration during the development of the Frontcountry education Program. According to the Outdoor Industry Association there are three times as many car campers and five times as many day hikers as there are backpackers in the U.S. The number of day hikers is projected to increase from 47 million people to 74 million people by 2050, and car campers are expected to increase from 42 million to 62 million by 2050. Various market trends were also considered in targeting day hikers and car campers. For example, according to a USDA Forest Service study day hiker days are projected to surpass the one billion days mark by 2020."

This game focuses on a specific region of the Potomac watershed called the Potomac Gorge, but the LNT principles could be applied to any part of the watershed.

Goal:

Understand the importance of the Leave No Trace ethic, particularly as it applies to the frontcountry or day–use parks.

Materials List:

- Gorgeous Gorge Frontcountry information for each student or group
- Game boards (11" x 17"), one for each group of four students
- The Gorgeous Gorge Game cards (one set for each game board)
- 1 die for each game board
- Instructions

Gorgeous Gorge Game

PROCEDURE

1. **Get Students Thinking About Parks:**

   Start the lesson by asking students about their visits to local parks. Do they visit any parks? Do they have favorites? What do they like to do when they go to a park? Find out if students have ever heard the terms "backcountry" and "frontcountry," and begin building a common language for the remainder of the module. The backcountry refers to areas inaccessible by car and where backpackers bring everything they'll need for a few days or a few weeks – including food, emergency supplies, tent, sleeping bag, etc. The frontcountry, as described above, refers to areas where people day hike or where they are able to drive and offload their gear.

2. **Highlight the Leave No Trace Frontcountry Ethic:**

   - You will want to ask students for their understanding of what "ethic" means.
   - The game will provide opportunities for students to discuss/debate the bulleted points, but discussing the seven main categories is helpful. See accompanying sheet.

3. **Directions to Play the The Gorgeous Gorge Game:**

   - Divide the class into groups of four and hand out board games, sets of cards, and dice.
   - Cut cards apart and shuffle them. Place them on the board face down in the designated spot.
   - Cut out and assemble playing pieces. Each player chooses a piece.
   - Turns rotate clockwise.
   - Roll die and move playing piece that number of spaces.
   - On designated spaces, pick a card, and answer the question. When your group reaches a consensus on an answer then the person to the right gets to roll the die and pick up the next card.
   - If you land on the social trail, you have to slide back, pick a card and answer the question. Then the next person rolls the die and hopes that you don't land on it again!
   - When everyone has completed the game, move on to the assessment.

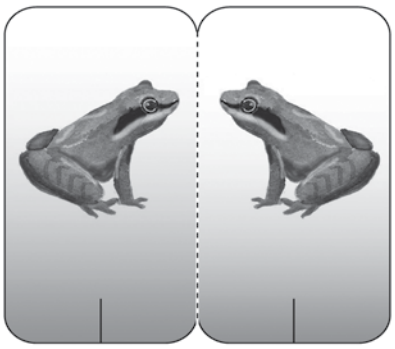
4. **Assessment: Ethics.**

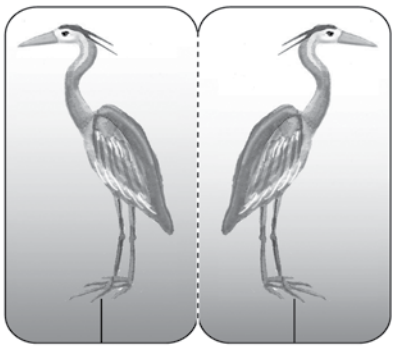
   When students have completed the game, ask them to list three ways in which humans can minimize their collective impact on the Potomac Gorge.

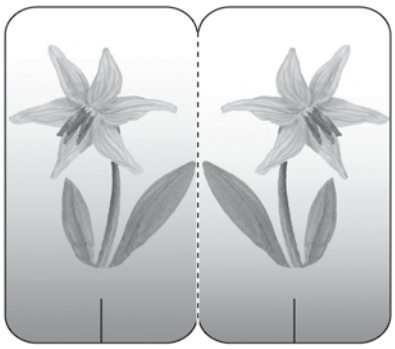
Gorgeous Gorge Game

ELABORATION

GAME PIECE







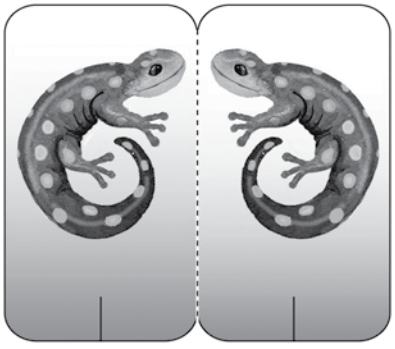
NOTCHES

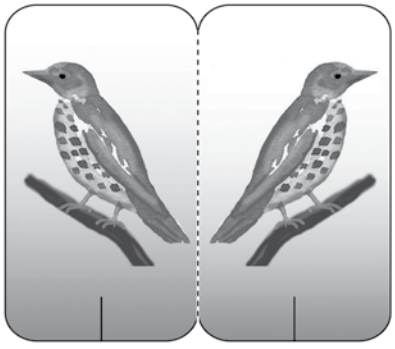
Wood Frog

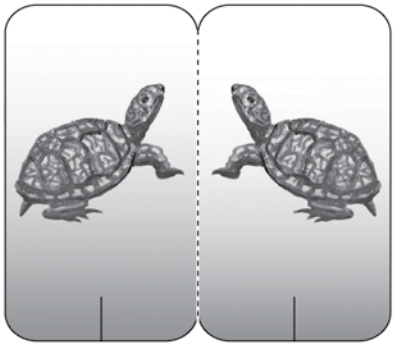
Great Blue Heron

Trout Lily

BASE STAND







Spotted Salamander

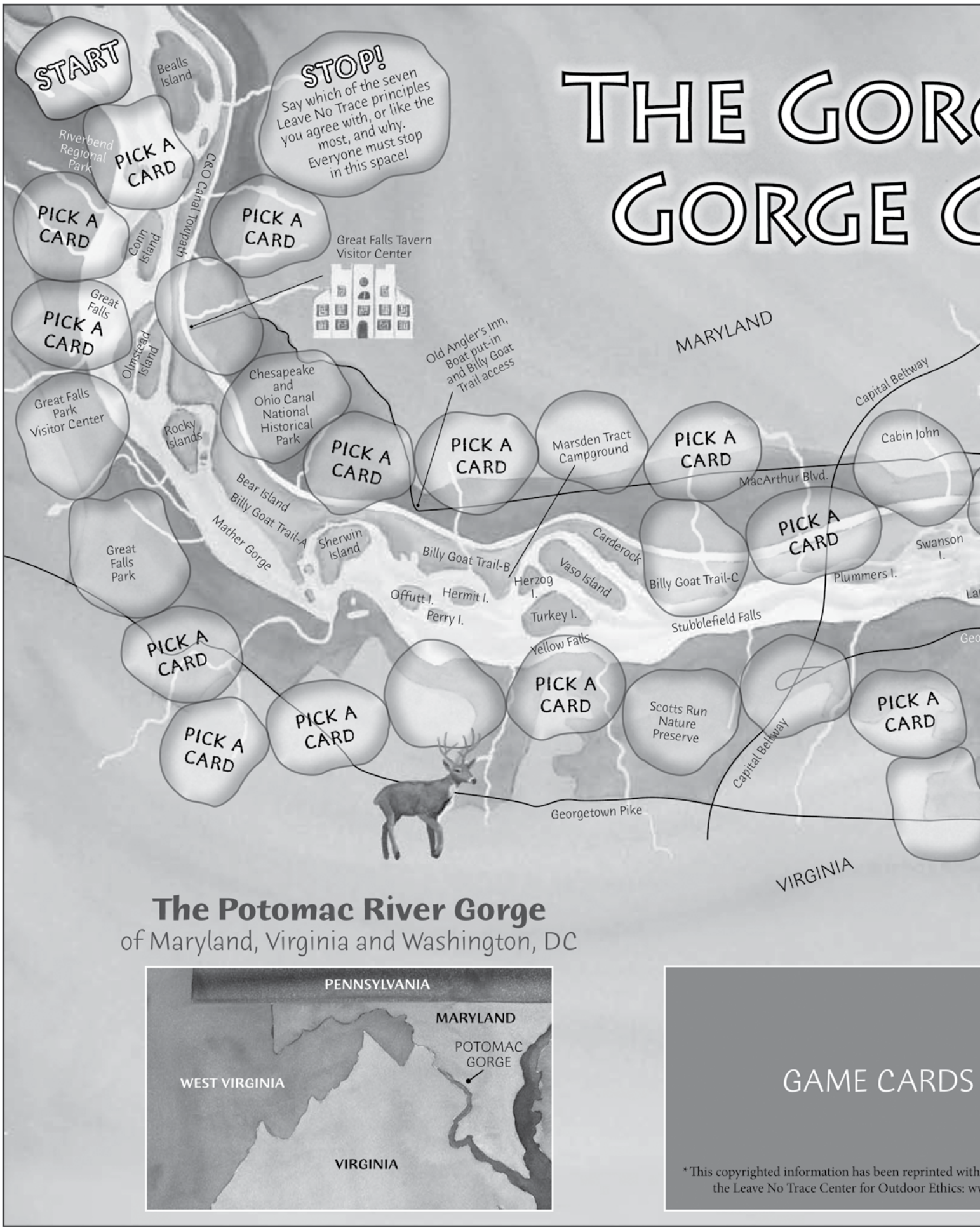
Thrush

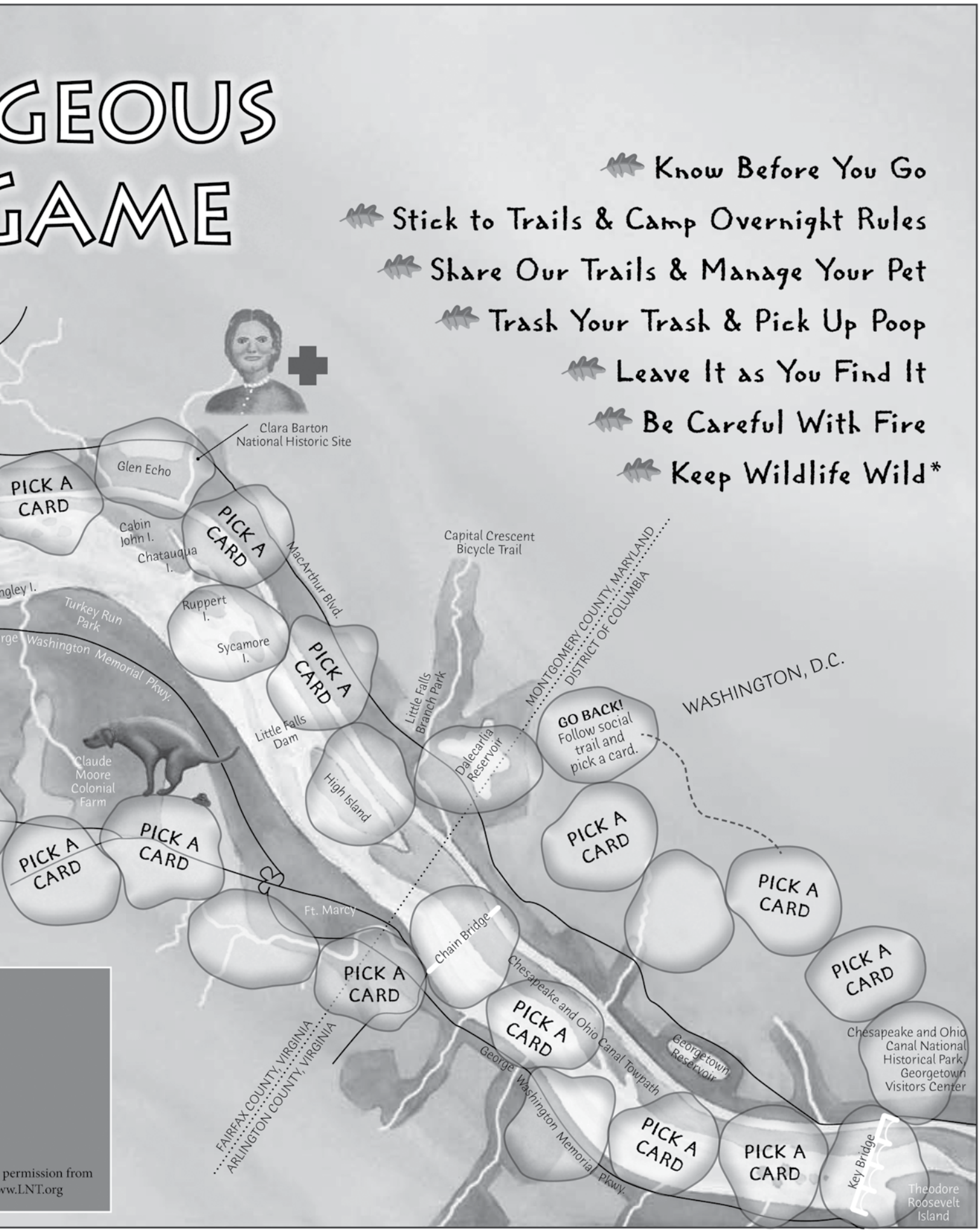
Box Turtle

Gorgeous Gorge Game

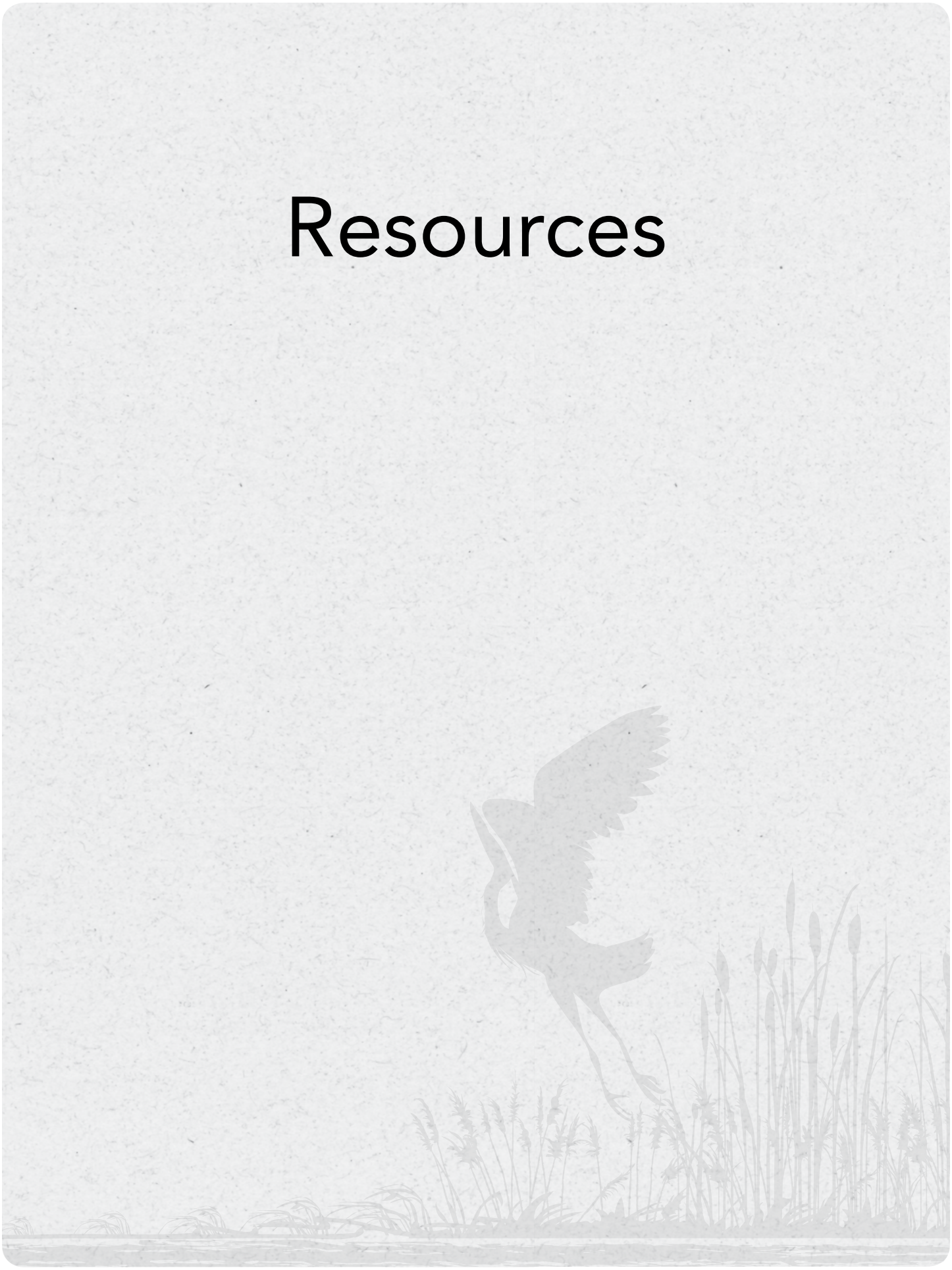
ELABORATION

How should you dress for the day if you don't know what the weather's going to be? KNOW BEFORE YOU GO	What research should you do before biking the C&O Canal towpath? Where can you stay if you want to make it an overnight adventure? KNOW BEFORE YOU GO
Some of the trails on Bear Island and other places can be tricky. What do you need to bring with you to keep from getting lost? KNOW BEFORE YOU GO	What research should you do before hiking the Billy Goat Trail on Bear Island? KNOW BEFORE YOU GO
You want to bring your dog, but pets can trample all over plants and small critters. How will you keep your dog on the trail? KNOW BEFORE YOU GO	It's a warm April day and you want to rent a kayak to paddle around Theodore Roosevelt Island? Can you? How would you find out? KNOW BEFORE YOU GO
Animals poop in the woods, so why can't your dog do it? Isn't all poop pretty much the same? KNOW BEFORE YOU GO	Does the Great Falls Tavern still serve ale to weary travelers? Why is this building so historic? KNOW BEFORE YOU GO
What tools can you use to learn about the area you're visiting? KNOW BEFORE YOU GO	Who actually owns the Potomac River? Do Virginia and Maryland split it right down the middle? KNOW BEFORE YOU GO





Resources



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. In 2007, the Intergovernmental Panel on Climate Change (IPCC) issued a report, written by hundreds of scientists who analyzed both the rate of climate change and the causes of this warming, stating that they had "very high confidence that the global average net effect of human activities since 1750 has been one of warming." The IPCC attributes the warming influence primarily to the increase in three key heat-trapping greenhouse gases in the atmosphere: carbon dioxide, methane, and nitrous oxide.

Resources

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.

How will climate change affect the ecosystems in the Potomac River watershed?

The effects will depend on our choices today. According to the U.S. Global Climate Change Research Program, temperatures in the Northeast are projected to rise an additional 2.5 to 4°F in winter and 1.5 to 3.5°F in summer over the next several decades. These temperature increases will impact us directly and indirectly:

- Winters are projected to be much shorter with fewer cold days and more precipitation.
- 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.

- 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 will create a big stress on people with asthma and other conditions that are aggravated by the heat.
- Hot summer conditions would arrive up to three weeks earlier and last up to three weeks longer into the fall.
- Sea level along the Mid-Atlantic coast is projected to rise more than the global average. This rise in water will continue up rivers like the Potomac, making the floodplains bigger than they are now. During storm events, the plants and animals in these 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 already showing signs of acidification** as a result of dissolved CO_2, 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 the 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.

Temperatures in the Potomac River watershed have already warmed by nearly 2° F since 1960. The United States Global Change Research Program models project increases in temperatures ranging from 2-3° C to as much as 5° C by the year 2100, with the largest increases in coastal regions. Water temperatures will rise in tandem with warmer air. These changing temperatures will have ripple effects on the organisms that inhabit the Potomac River watershed, including humans.

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. 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.

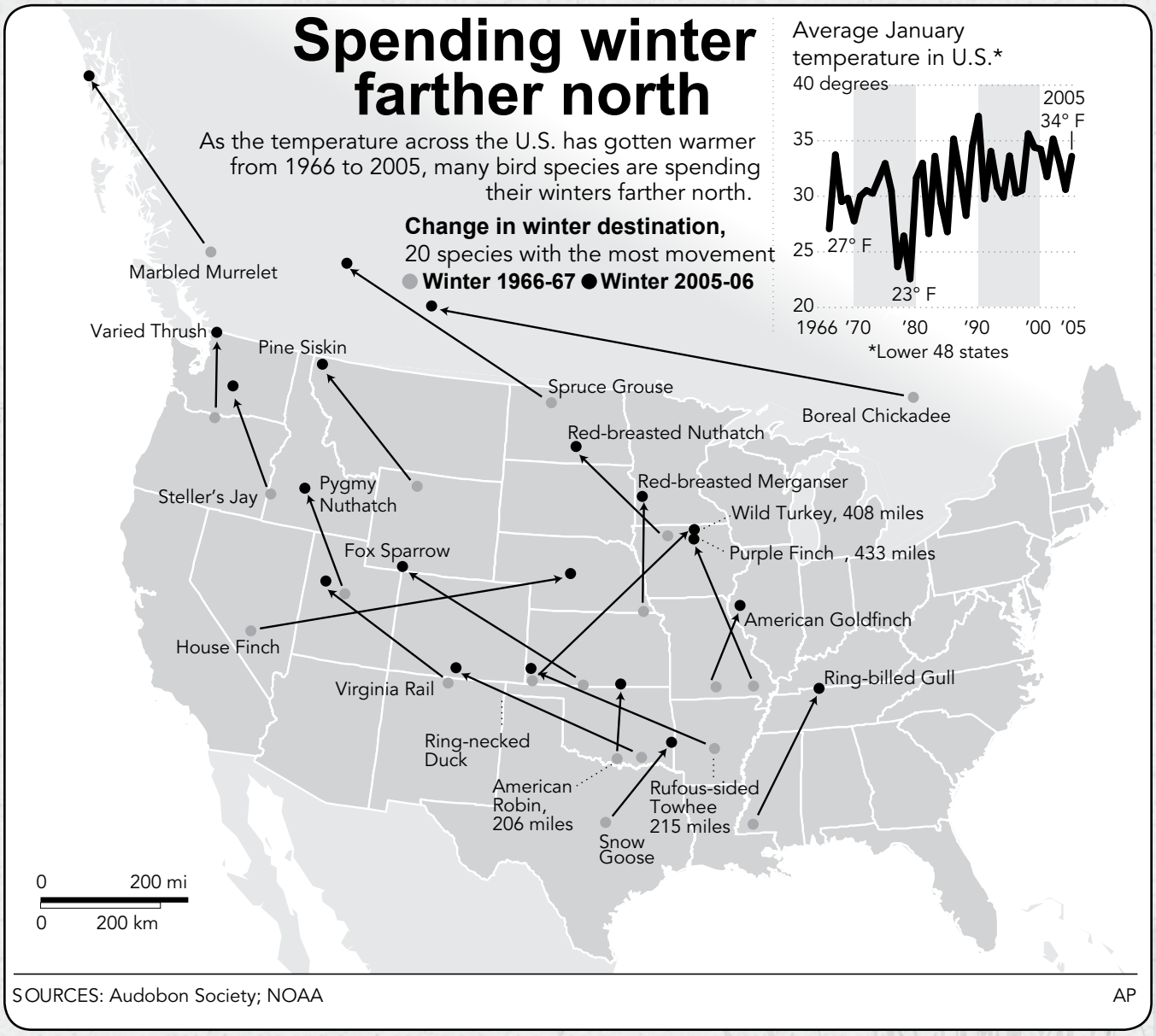
Benthic macroinvertebrates respond more quickly and predictably to changes in the environment, such as increased water temperatures, than vertebrates such as fishes and amphibians. You may find vastly different species of macroinvertebrates on a field study in future years.

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.



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. Exotic 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.