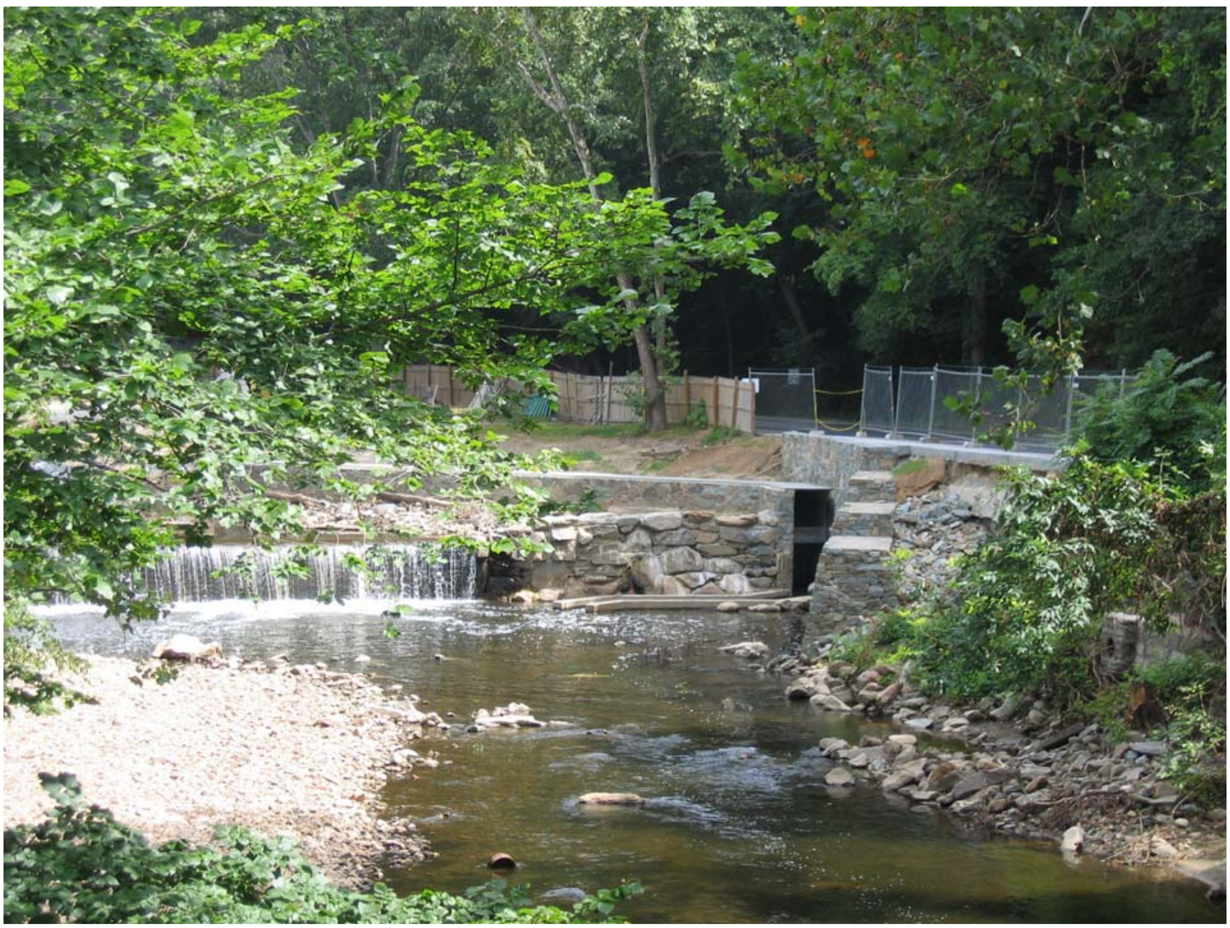
Bridging the Watershed

An Outreach Program of the Alice Ferguson Foundation
in Partnership with the National Park Service and Area Schools

Herring Highway

A Study of a New Fish Passage for River Herring



A Curriculum Module Written for Rock Creek National Park

Teacher Guide

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Herring Highway

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Herring Highway Curriculum Design

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Enduring Understandings	• When people change natural areas to suit their needs, their changes may interfere with survival of some organisms. • There are restoration methods that allow fish to resume their ancestral migration routes, increasing habitats for communities of organisms.	• Some fish migrate between fresh water streams and oceans. • Some migrating fish return to the place they were spawned to breed.	Fish have identifiable differences.	• National parks include lands that have been important to humans for generations because of the abundance of natural resources. • National parks preserve natural and cultural resources. • When people change natural areas to suit their needs, their changes may interfere with survival of some organisms.	When people change natural areas to suit their needs, their changes may interfere with survival of some organisms.
Essential Questions	• What kinds of structures block fish passage? • What kinds of interventions can help restore fish migration routes?	• What are anadromous fish? • How is their life cycle different from other types of fish?	How can the different kind of fish be identified?	Are fish ladders successful in restoring migrating routes for fish?	What in the environment impacts the survival rate of anadromous fish?
Performance Tasks	• Students will design and draw a fish ladder to overcome a set of obstacles for migrating fish. • Students will compare their fish ladder to the one at Peirce Mill dam and analyze why their design will/won't work.	Students will create a foldable that includes the life cycle stages of the river herring in the Chesapeake Bay watershed.	Students will draw and name common fish found in Rock Creek using basic fish anatomy characteristics.	Students will collect authentic data about habitat assessment and water quality, and conduct a fish census at two sites in Rock Creek.	Students will determine the environmental impacts that affect the survival rate of anadromous fish.

FISH FACTS: How much do you already know about fish?

<u>This is NOT a TEST</u>. This activity is called a pre-conceptions survey. On your worksheet, you will find the 22 questions listed below and a space for your answers along with a space for the correct answer if you didn't get right. This activity is not graded. It's a fun way to find out what you already know - and don't know - about the topic you are going to study.

The following set of questions (some have been gathered from factmonster.com) is designed to be used as an engagement to this module. An engagement is intended to increase curiosity and interest in students and give the teacher an opportunity to assess students' background information. Engagement activities are not graded, and the student worksheet has space for students to total how many facts they already knew and space for them to write the correct answers.

1. **Which group of vertebrates has the most species?** *Fish. Quoted estimate is 20,000*

2.. **What branch of zoology is the study of fish?** *Ichthyology*

3. **Is the plural of fish fish?** *Yes, if you're referring to one species of fish. It is correct to say fishes if referring to two or more species of fish.*

4. **Do fish breathe air?** *Yes, but not directly in the lungs as mammals—except for some tropical fish, they actually breathe oxygen, not air. As water passes over a system of extremely fine gill membranes, fish absorb the water's oxygen content. Gills contain a network of fine blood vessels (capillaries) that take up the oxygen and diffuse it through the membranes.*

5. **Do fish sleep?** *It all depends on the definition of sleep. To most animals it means their eyes are closed, and they are at rest. Most fish, however, don't have eyelids (except for sharks). Also, while some deep ocean fish never stop moving, and a great many fishes live nearly motionless lives, most fish do rest. Usually they just do what we might call daydream—they float in place or wedge themselves into a spot in the mud or coral. Some even build themselves a nest.*

6. **How can you tell the age of a fish?** *By counting growth rings on fish scales, much like counting rings on a tree.*

7. **How long do fish live?** *A few weeks or months to 50 years or more (sturgeons).*

8. **How do fish swim?** *Primarily by contracting bands of muscles in sequence on alternate sides of the body so that the tail is whipped very rapidly from side to side in a sculling motion. Vertical fins are used mainly for stabilization.*

9. **What fish are the fastest swimmers and how fast can they swim?** *Tunas and tuna-like fish, billfish, and some sharks can reach 50 miles/hour in short burst. Sustained speeds generally range from about 5 – 10 miles/hour among strong swimmers.*

10. **Which fish swims the slowest?** *The seahorse swims the slowest at a rate of 0.01 miles/hour.*

11. **Can fish swim backwards?** *Most don't; however, one member of the eel family does.*

12. **Do fish chew their food?** *Not in the same way as humans. Carnivorous fish like sharks use their sharp teeth to seize and hold prey while swallowing it whole or in large pieces. Bottom dwellers such as rays are equipped with large flat teeth that crush the shellfish they consume. Herbivorous fish (grazers) often lack jaw teeth, but have tooth-like grinding mills in their throats called*

pharyngeal teeth. Fish would suffocate if they tried to chew, for chewing would interfere with the passage of water over the gills,which is necessary for breathing.

13. **Can fish distinguish color?** *No, most fish are colorblind. Fish can see color shadings, reflected light, and shading.*

14. **Why do fish sometimes have a strong odor?** *Most fish are almost odorless. Fish begin to smell "fishy" because of deterioration when improperly stored and oxidized fats and acids that are released through bacterial and enzymatic action.*

15. **Do all fish produce offspring by laying eggs?** *No, some fish give birth to living offspring such as sea perches of the Pacific Coast and several kinds of sharks. A male seahorse carries the eggs in his pouch until they hatch.*

16. **Is there much salt in fish?** *Very little in most. More than 240 species contain so little salt that doctors recommend them in salt-free diets. Shark meat is salty—as salty as the sea the shark lives in.*

17. **Do fish travel very far?** *Some do. Anadromous fish, born in fresh water, spend most of their lives in the sea and return to fresh water to spawn. Salmon, shad, blueback herring, alewife herring, strped bass, and sturgeon are common examples. A catadromous fish does the opposite; it lives in fresh water and enters salt water to spawn. Most eels are catadromous.*

18. **How much electricity can an electric eel discharge?** *350 volts, but as much as 650 volts have been measured*

19. **Sometimes fish swim in groups and at times are called schools of fish. A group of jellyfish is called a smack. What is a group of herring called?** *Seige*

20. **What is a herring?** *Herrings are small oily fish of the genus Clupea found in the shallow, temperate waters of the North Atlantic, the Baltic Sea, the North Pacific, and the Mediterranean.*

    All of the 200 species in the family Clupeidae share similar distinguishing features. They are silvery colored fish that have a single dorsal fin. Unlike most other fish, they have soft dorsal fins that lack spines, though some species have pointed scales that form a serrated keel. They have no lateral line and also have a protruding lower jaw somewhat like a bulldog's. Their overall size varies greatly from species to species: the Baltic herring is small, usually about 14 to 18 centimeters in length, and the Atlantic herring can grow to about 18 inches in length and weigh up to 1.5 pounds (700 g).

21. **What is a herringbone pattern and what does it have to do with fish?** *Herringbone is a pattern of columns of short parallel lines with all the lines in one column sloping one way and lines in adjacent columns sloping the other way; it is used in weaving, masonry, embroidery, etc. It is based on the pattern of the rib bones coming off of the spine in a herring.*

22. **What does the phrase "red herring" mean?** *Until over-fishing depleted their ranks, herring were so numerous and so important as a staple foodstuff to both America and Europe that many writers referred to the Atlantic Ocean as "the herring pond." The downside of the little critters, however, is that they spoil very rapidly and become inedible. The only practical way to preserve herring is to cure them with a combination of salting and smoking, and those herring most heavily cured turn a deep crimson color from the process. Thus, red herring.*

Curing herring in this fashion not only preserves the fish and changes its color, but also gives it a distinctive smell, and it is this aspect that contributes to the modern meaning of "red herring." In training hounds to hunt foxes, these red herrings, dragged on a string through the woods, were used to lay down a scent trail for the dogs to follow. There is also some evidence that red herrings were, later in the training process, sometimes dragged across the scent trail of a real fox to test the ability of the hounds to ignore a false clue and stick to the scent of the fox. From this practice comes our use of "red herring" to mean a false clue or bogus issue designed to confuse one's opponent. "Red herring" first appeared in the literal "smoked fish" sense around 1420, but the figurative "phony issue or false clue" sense didn't appear until around 1884.

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Herring Populations Changed Over Time

Historically, river herring (blueback herring and alewife species) packed streams in such large numbers that settlers called them "glut" fish.

"In the spring of the year, herrings come up in such abundance into their brooks and fords that it is almost impossible to ride through without treading on them," wrote early Chesapeake historian Robert Beverly in 1705. Herring were so thick, he wrote, that "*even the freshest of rivers…stink of fish*."

River Herring

River herring once supported important commercial fisheries along the Atlantic coast, but that has changed in recent years:

- Commercial landings of Atlantic coast river herring reached historic highs in the late 1950s at around 75,000,000 pounds per year.
- Current totals are less than 2,000,000 pounds per year.

Causes of Herring Population Decreases

Population collapses were blamed on:

- foreign fishing fleets—before fishing restrictions were imposed in the 1970s
- loss of essential spawning and nursery habitat because of water pollution
- construction of dams and other blockages to fish migrations

Why Should You Care?

Today, most commercially-caught herring are ground up for fishmeal, pet food, or used as bait, so why should you care?

It Will Help Restore the Potomac River & Chesapeake Bay Watersheds

Allowing river herring to return to their native spawning (releasing eggs and sperm for reproduction) grounds is one of the pieces that will promote the restoration of the Potomac River and greater Chesapeake Bay. Whenever any species is reduced or eliminated, the entire food web suffers. It's a bit like knocking down the first in a line of dominoes, and **people are part of that line**. Humans constantly alter environments to benefit human needs, often at the expense of other species. We can repair environments to benefit the species previously harmed by our actions. Some mistakes can be corrected.

continued on next page

Why Should You Care? (*continued*)

River herring are planktivores (i.e., plankton-feeders) and eat primarily zooplankton, though they may eat:

- fish eggs
- crustacean eggs
- insects and insect eggs
- small fish

In turn, almost everything likes to eat them, from other fish to reptiles, amphibians, mammals, and birds. These herring species are considered an important forage base for large, near-shore predators such as striped bass. Humans enjoy eating herring pickled and salted.

Research has shown that the large numbers of river herring that once glutted headwater streams were an important source of nutrients in those areas. This provided other ecological benefits as well. One study, for instance, found that the deaths of migrating alewife reduced sedimentation rates in lakes by furnishing nitrogen and phosphorus, which stimulated the growth of organisms that devoured leaf litter.

Herring Migration & Imprinting

River herring spend most of their lives in the salt water of the Atlantic Ocean. Adults return every year to spawn in the streams where they were born. Spawning is releasing eggs and sperm into the water to create new eggs and the next generation of river herring.

Herring "imprint" on the rivers where they were born, which means that as adults they have a drive to return to those places to spawn. This is thought to happen because various stimuli in the environment "program" the fish to return there as adults. Every stream has different characteristics in its water due to the types of rocks and soils and other factors that affect water quality, so the adult fish can "recognize" their correct stream.

What Will You Do in This Module?

You will have the opportunity to:

- learn about river herring, their characteristics, and migration patterns
- study the problems river herring encounter to maintain their species in this watershed and the methods designed to correct the problems
- learn basic fish identification
- conduct a field study at Rock Creek Park in which you will collect data about the kinds and numbers of fish present in Rock Creek
- engage in an activity that will address the perils migrating fish have in their journey from spawning grounds to the Atlantic Ocean and back again

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Lesson 1. What's the Dam Problem?

Objectives

- To design and draw a fish ladder that will overcome a set of obstacles (things that stop them from moving upstream) for migrating fish
- To compare your fish ladder to the one at Peirce Mill dam and analyze why your design will or won't work

So, What's the Dam Problem?

River herring migrate from the Atlantic Ocean and up Rock Creek to spawn. Peirce Mill dam (see picture on the cover of this module) in Rock Creek makes it impossible for fish to swim any farther upstream from that point.

River herring need three things in order to complete this necessary journey upstream:

- no high barriers (they cannot jump like salmon can)
- resting pools along their pathway
- attractive water flow (not too fast or too slow)

Question to Think About: Peirce Mill Dam prevents fish from meeting which one of these three needs?

Why is Peirce Mill Dam in Rock Creek?

In the early 1800s, a number of mills were built along Rock Creek. The power of flowing water was used to turn water-wheels to provide energy for grinding grain and bone, sawing lumber, and processing other raw materials. There were eventually nineteen creek side mills, eight of them powered by water, transforming the area into a thriving agricultural and industrial complex. Most of the mills are long gone, but you can still see Peirce Mill, built in 1820, in Rock Creek.

Mill Wheel at Peirce Mill

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Why Not Just Remove the Dam?

Well, why not blow up the dam? Peirce Mill dam is a historic structure and a beloved icon of Rock Creek National Park. The sole survivor of the milling era, Peirce Mill is preserved and protected today by the National Park Service and is listed on the National Register of Historic Places. The park's mission is to preserve and protect the plants, animals, structures, and the landscape. The scenery is vital to the look and feel of the park that has been a public area since 1890.

Every Problem Has a Solution

As a solution to this problem, a fish ladder was constructed at Peirce Mill dam in 2006. This was only a part of a huge project to remove multiple barriers to fish migration in Rock Creek funded by the Woodrow Wilson Bridge construction project. As part of large projects such as this one, which cause environmental harm, there are laws requiring that the organizations or companies involved "make up" for the damage they cause by paying for the creation, restoration or preservation of another area of equal or greater ecological importance. This is called "**compensatory mitigation**."

Aerial View of the Woodrow Wilson Bridge between Maryland and Virginia

Legislators from Maryland, Virginia, and the District of Columbia determined years ago that a new Woodrow Wilson Bridge was needed because of the age of the existing bridge, traffic congestion and safety issues.

One of the necessary parts of planning the construction of a new bridge is evaluating the impact that construction will have on the environment, deciding how the damage can be avoided, and considering whether any alternatives are possible.

Impacts: Building a new Woodrow Wilson Bridge would require sinking massive supports into the river bottom, a process requiring dredging 340,000 cubic yards of sediments up from the bottom. Not only would disruption of the river bottom and suspension of sometimes toxic sediments damage the aquatic environment, but sediment disposal would disrupt nearby wetland ecosystems.

Alternatives to Avoid Damages: After considering possible alternatives, it was decided that no feasible alternative would damage the environment less, and a new bridge was necessary.

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Every Problem Has a Solution *(continued)*

Results: As part of the compensatory mitigation plan, the following changes to fish migration blockages have occurred:

- Three abandoned sewer lines which blocked the fish migration were removed.
- Two concrete fords (paved areas for carriages and cars to cross a river or stream) have been removed.
- At the historic Milkhouse Ford, contractors lowered the ford, which increased the depth and flow of water over the ford, making fish passage possible. This one cannot be removed because of its historic value.

Milkhouse Ford (c.1989)

- At active sewer lines, boulder step-pools were created to establish grade control and the appropriate backwater condition that allows fish to swim over the pipes.
- A Denil fish ladder was constructed at Peirce Mill Dam to allow fish to bypass the dam, which they cannot jump over.

<u>Task 1</u>
Design a Way for Fish to Get Past the Dam

Before we proceed with information about the fishway that was built at Peirce Mill Dam, let's see if you might have a solution to the dam problem. There is generally <u>more than one solution to a problem</u>.

<u>Your task is to create a method for fish to get above the dam without blowing it up.</u> On page 4 you will find the space to draw your solution to the obstacle the dam has created for the fish. Draw the waterway, the dam, your design for fish passage, and label all parts. Don't forget to show the direction of flow of water. Keep in mind that the fish—river herring in this case— can't jump over this obstacle; they need resting places, and they need an adequate flow of water.

On page 3 of your worksheet booklet you will find the rubric that will provide you with specific items that will be used to evaluate your design. Remember that your design will be evaluated on creative, not artistic, ability.

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Fish Ladders

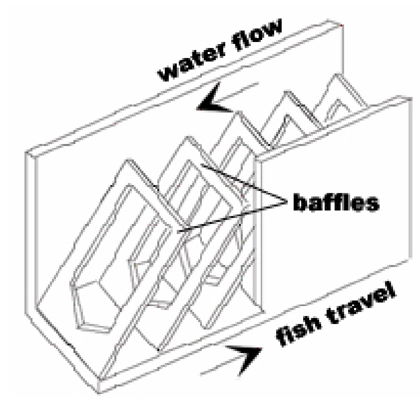
Since each situation is different, engineers consider many factors when designing a fishway for a certain obstacle. Some of the factors are the:

- height of the obstacle
- number and kinds of fish that will use the ladder
- speed and depth of the water
- pattern of currents in that part of the river

There are four basic types of fishways: pool-weir, vertical slot, steep pass, and Denil. This section focuses on the **DENIL fish ladder**. For further information on the other three types of fish ladders, a search on the World Wide Web will provide lots of resources.

Denil Fish Ladders

The original design for a Denil fish ladder was developed in 1909 by a Belgian scientist, G. Denil. A Denil fish ladder is made by fitting a series of slanted slats (or "baffles"), with a hole cut in each one, into a rectangular channel of the fishway. The fishway is angled up to allow the fish to swim to the higher reaches of the stream, above the dam. The baffles are slanted toward the flow of water to reduce the current through the ladder, especially right in the middle. Fish swim through the baffles until they reach the top of the ladder where it joins the waterway above the dam.



Denil Fish Ladder Diagram

Denil fish ladders can be built with different sized baffles and openings to suit even rivers with fast-moving currents and accommodate many kinds of fish. Resting pools can be included in the design if the length of the blockage makes this necessary.

The picture to the left, the fish ladder at Peirce Mill Dam, taken before the fish ladder was operational, shows the view looking down from the top. Fish will swim upwards through the baffles to the stream above the dam.

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Task 2
Analyzing Fish Ladders

Look below at the pictures of the Denil fish ladder at Peirce Mill Dam. Compare the design of this fish ladder to the one you created, and **answer the following questions on page 5 of your worksheet.**

- How does your design compare to the Denil fish ladder design?
- Explain why you think your design would work for fish.

1. At the lower end of the channel, fish feel the flow of water and swim into the fish ladder.

2. Close-up view of the path to entrance to the fish ladder

3. Opening to the fish ladder

4. The long narrow wall to the right of the person standing above the dam is the fish ladder containing the baffles that allow the fish to climb and rest to get above the dam.

5. Opening at the end of the fish ladder where fish re-enter Rock Creek above the dam at Peirce Mill. The bars keep debris from washing into the fish ladder during flooding. The cover of the fish ladder will be removed during migration to allow for natural light conditions, encouraging fish to swim through the ladder.

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Lesson 2. The Little Fishes That Could

Objective To create a "foldable" that includes the life cycle stages of the river herring in the Chesapeake Bay watershed

Migrating Fish Most species of fish are either freshwater (e.g., lakes, streams, rivers, ponds) or saltwater (e.g., seas, salt lakes, oceans) fish, completing their entire life cycle in one type of water. They may migrate to different locations within their range, but they are so adapted to either fresh or salt water that they cannot survive in the other type.

There are other fish that migrate between salt water and fresh water, living most of their lives in one, and periodically migrating through brackish water to get to the other. Fish that migrate between fresh and salt water are called "**diadromous**," and there are three types:

- **AMPHIDROMOUS** fish move between fresh and salt water during some part of their life cycle for a purpose OTHER THAN breeding. Examples include fish that follow seasonal changes in water temperature or food sources (e.g., sheepshead minnow).
- **CATADROMOUS** fish hatch in salt water, move to fresh water to mature, and return to the sea to breed (e.g., American eel).
- **ANADROMOUS** fish hatch in fresh water, move to salt water to mature, and return to fresh water rivers and streams to breed (e.g., salmon, alewife, shad, blueback herring).

In this lesson, you will learn about two species of **anadromous** fish: blueback herring and alewife. These species together are called river herring. River herring spend most of their lives in the salt water of the Atlantic Ocean. Adults return once every year to spawn (releasing eggs and sperm into the water to reproduce) in the streams where they were born.

These two species of fish have not been able to return to their native spawning grounds in Rock Creek for over 200 hundred years, and scientists hope the Denil fish ladder at Peirce Mill dam will allow them to do so.

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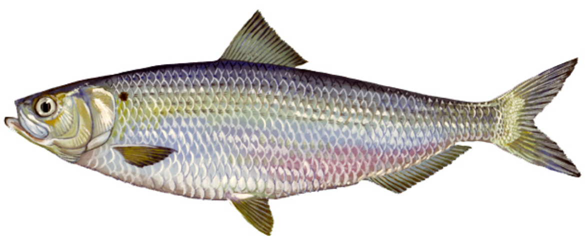
Comparing River Herring

The following graphic provides you with some basic characteristics of the two fish and a drawing of what they look like. Many times both are grouped together and referred to as “river herring.” As you can see from the drawing and characteristics, they look very similar.

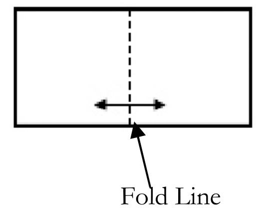
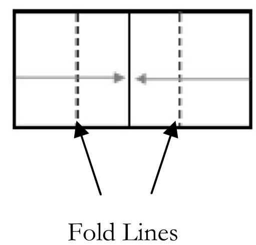
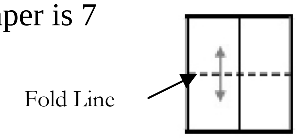
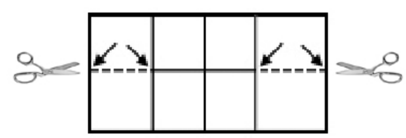
River Herring	
Blueback Herring (*Alosa aestivalis*)	**Alewife** (*Alosa pseudoharengus*)
	
Back Color	
blue-green	gray-green
Eye Width	
equal distance between the front of the eye and the tip of the snout	greater distance between the front of the eye and the tip of the snout
Body Shape	
slightly more slender and elongated than alewife	slightly deeper than the blueback
Dorsal Area (top of the fish) Color	
deep bluish-green	Bronze
Migration Range	
Nova Scotia to northern Florida	Newfoundland to South Carolina
Spawning Period	
March through May	February through April
Length	
about 38 centimeters	about 27 centimeters

continued on next page

Task 3
Create a Foldable

The following information will provide you with much information about the lives of river herring, their migration, and the stages of their life cycle. **To show your understanding of the material, you will create a foldable.** "Foldables" are clever and interesting ways to learn new information.

You will be given a separate, legal-sized piece of paper with a map drawn on it to complete this activity. Follow the steps below to make a blank foldable. Dotted lines are the fold or cut lines.

Step	Action
1	Turn one sheet of white, legal-size (8 ½ x 14 inches) paper so that the longest side is running from right to left (as in the picture to the right). The map should be face-down on the table so that you can't see it. Fold the paper in half, from side to side, like a book. The map will now show on the outside along the fold line. 
2	Open the folded paper, lay it flat, and fold each of the ends **IN** towards the center fold. Each end should meet at the center fold. Crease the folds. You now have a paper with an opening between your two flaps that runs from top to bottom. They look like cabinet doors with a map on the front that meet in the middle of your paper. 
4	Keeping the paper folded as in step 2, fold again, in half, from top to bottom, so that the flaps are hidden inside and the folded paper is 7 x 4 ¼ inches. 
5	Open the folded paper so that it is completely flat on your table, and using a pair of scissors, cut each flap at the fold (see dotted cut lines on the diagram to the right). You should now have four flaps and the inside sheet should have four quadrants created by two folds. 
6	Each quadrant should be 3 x 4 ¼ inches. **You have constructed your foldable!**

The Map

On the map, locate each of the following bodies of water:

1. Rock Creek
2. Potomac River
3. Chesapeake Bay
4. Atlantic Ocean

continued on next page

<u>Task 3</u>
Create a Foldable
(continued)

Follow the following five steps to complete your foldable for the life cycle of the river herring.

Step	Action
1	Start in the upper left-hand quadrant and **NUMBER** <u>the outside corner of each flap with a number, 1-4</u>, moving around counterclockwise, so the upper left-hand quadrant is 1, the lower left quadrant is 2, etc.
2	Next, **CUT AND PASTE** <u>the labels</u>, on page 6 of your worksheet, to show the correct bodies of water represented. ▪ Quadrant 1.) Rock Creek ▪ Quadrant 2.) Potomac River ▪ Quadrant 3.) Chesapeake Bay ▪ Quadrant 4.) Atlantic Ocean.
3	**READ** <u>the information in the section called, "River Herring Life Cycle</u> Information," on page 16.
4	Using what you learned about the herring life cycle, **CUT OUT** <u>the pictures of stages of the herring life cycle,</u> on page 6 of your worksheet, and **GLUE** each stage on the outside of the flap that matches where that life stage takes place.
5	Under each flap of your foldable, **WRITE** <u>the important information about each stage of the herring life cycle</u>. For example, information about what happens during the egg stage should be written inside your foldable under the flap that has the egg picture on it. <u>Make certain your notes answer the following questions for each life stage</u>: ▪ <u>When</u> are they are at that location? ▪ <u>How long</u> do they stay at that location? ▪ <u>Why</u> are they at that location for that life stage? ▪ <u>Other</u> information that may be important

In the end, each section of your foldable should have:

- a **picture** of the correct herring life stage on the map on the outside flap
- the **location** where the herring are during that life stage on the outside of the flap
- **notes** about that stage of the life cycle under that flap

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River Herring Life Cycle Information

We call the alewife and blueback herring species "river herring." River herring spend most of their adult lives in the open ocean, returning to the rivers and creeks of their birth only once a year to spawn (release eggs and sperm into the water). During spawning, female adults from both species of river herring produce and release 60,000 – 300,000 eggs into the upstream waters in the creeks or rivers where they were born. For our study, we are going to focus on those herring which spawn in Rock Creek. Immediately after spawning, adults migrate quickly downstream and back to the open ocean.

Spawning is driven by water temperature. Herring start spawning in the spring when water temperatures get above 13-15^o C and end when the water temperature gets above 27^o C. Therefore, spawning time is different in different streams. Adults will return to the same stream to spawn for 2 – 4 years in a row before they die at around age 8.

Eggs float downstream to larger rivers with the motion of the water. Eggs hatch after 2 -3 days at 22 – 24^o C. When the fry (young fish) hatch, they are 2.5-5.0 mm long, and they feed for the first few days by absorbing their yolk sacs. After the first 3-5 days, the fry begin to feed, eating mostly plankton. These larvae can't control their movement, so they drift passively further downstream into "nurseries" which are located in tidal marsh areas. For the fish we are studying, these nurseries are in the marshes along the Potomac River.

The fry are considered juveniles after about a month, at which point they are approximately 2.5 cm long. At this stage, they have most of the characteristics of adults, with developed scales and the typical silvery coloring. Juveniles gradually move downstream into estuary areas throughout the summer in response to the increasing water temperatures. In our area, this estuary is the Chesapeake Bay. They will move downstream so that, by fall, they reach the mouth of the estuary and enter the ocean, where they will remain until they reach adulthood and can reproduce. Many juveniles spend their first winter close to the mouth of the river or among submerged aquatic vegetation beds in the lower Chesapeake Bay. One study estimated that one out of every 80,000 spawned alewife eggs survived to the juvenile stage.

River herring females usually reach maturity by age 4-5, whereas males of both species generally mature at an earlier age (ages 3-4). Most adults and sub-adults spend the majority of their lives at sea following a north-south seasonal migration along the Atlantic coast, only returning to rivers to spawn. Bluebacks are found at depths of 27 - 55 meters throughout their offshore range. Little information is available on the life history of sub-adult and adult river herring after they migrate to the sea as juveniles, and before they mature and return to freshwater to spawn.

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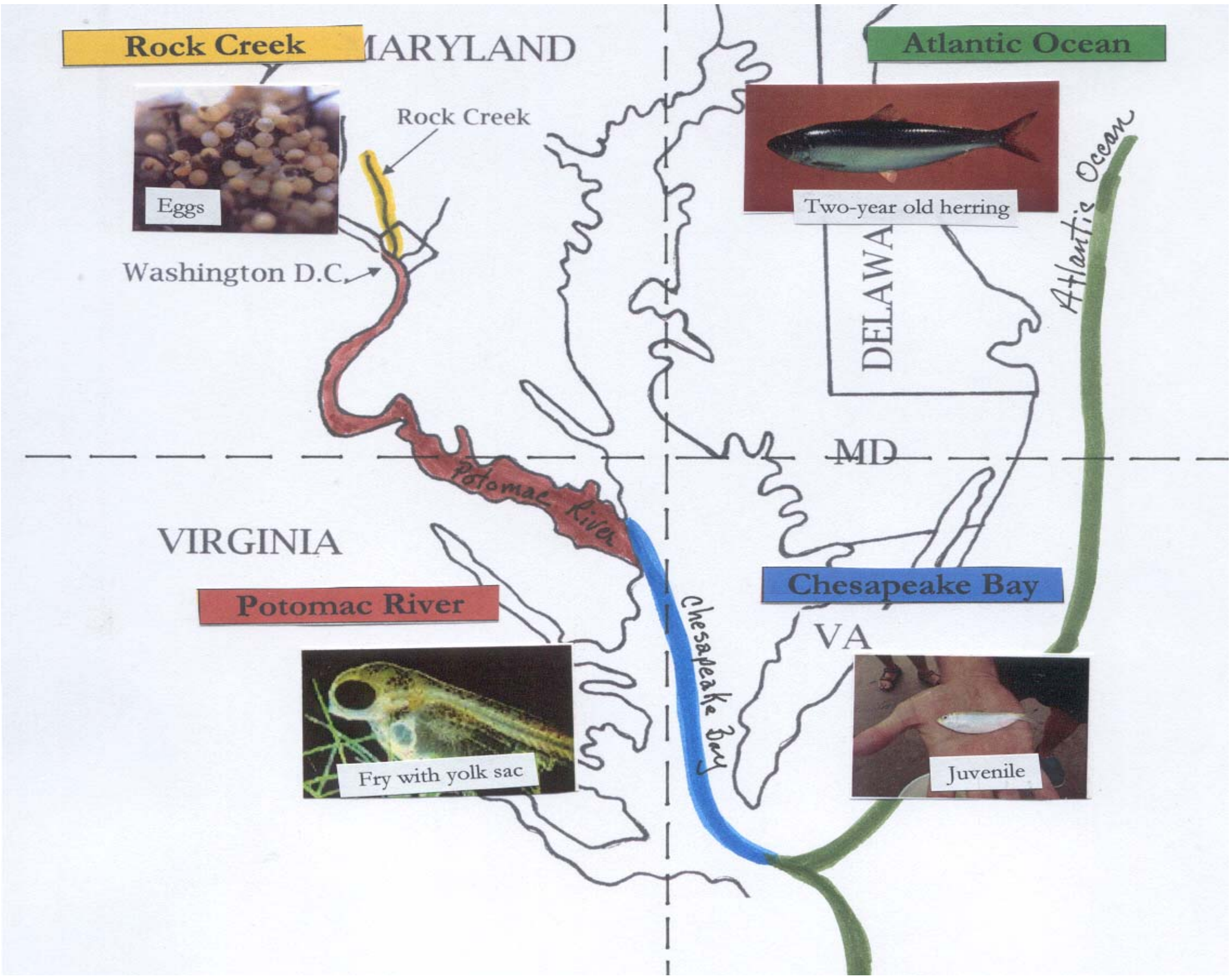
The <u>front of the foldable</u> should end up looking like the anchor paper below. The horizontal broken line indicates where the paper was cut, and the vertical broken line is where the map formed when the paper was folded together. Students may need to extend lines on the map that may have been cut off due to printing problems to complete the coastline along the Chesapeake, and they may need some assistance identifying the waterways.



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The text below represents the typical information students should write <u>*under each flap of the foldable.*</u>	
Rock Creek **When?** Eggs are spawned in the spring **Why?** Spawning is dependent on temperature. River herring need freshwater streams with a good flow of water and gravely/clear sand river bottom. **How Long?** It starts when the water temperature gets above 13 – 15^{o}C, and ends when temperatures get above 27^{o}C. **Other:** 60,000 – 300,000 eggs spawned per adult female each spawning season.	Atlantic Ocean **When?** From fall of year one until fish reach maturity at 3 – 4 years for males; 4 – 5 years for females **Why & How Long?** Sub-adult and adult river herring spend most of their lives in salt water, only returning to freshwater to spawn. **Other:** Sub-adult and adults migrate north and south seasonally along the Atlantic Coast.
Potomac River **When?** In the spring, eggs hatch between 2 -3 days. **Why are they there?** Fry can't control movement, but float passively downstream to nurseries in the larger river. **How long?** This stage lasts for the first month, after which they are considered juveniles. **Other:** Fry hatch at 2.5 – 5.0 mm long, feed on their yolk sack for the first 3 – 5 days, and eat plankton after the yolk sack is gone.	Chesapeake Bay **When?** The juvenile stage lasts from end of the first month until fall, during this time they move downstream into the estuary (Chesapeake Bay) and then into the ocean. **Why?** Juveniles move downstream to the ocean in response to increasing temperatures through spring and summer. **How Long?** They will remain in the bay 4 – 5 months.

Lesson 3. Fishin' For a Name

Objective

To draw and name common fish found in Rock Creek using basic fish anatomy characteristics

Scientific Classification

Most people identify fish using a common name, but that gets confusing because more than one fish might have the same common name in different places, or one species might have several common names. Scientists need to know exactly which fish they are identifying, so they use scientific names.

In the eighteenth century, **Carolus Linnaeus** developed a classification system based on the external features of organisms. He used a two-term naming system called **binomial nomenclature**. Each organism is given a two-word Latin name.

- The first word is the **genus** (division in classification between family and species) to which an organism belongs, and this is capitalized.
- The second word represents the **species** (group of organisms that normally interbreed in nature to produce fertile offspring), and it is not capitalized.

In print, both names are written in *italics*. If written by hand, both names should be underlined.

Example: The scientific name for the Blueback Herring found in the District of Columbia is, *Alosa aestivalis*. As an aside, Linneaeus referred to herring as "*Copiosissimus piscis*"; in other words, the most prolific fish.

How to Identify a Fish

Fish have different characteristics, or things about their bodies, that allow us to tell one species from another. In this activity, you will be learning about these differences and how to identify fish you will be catching during the field study.

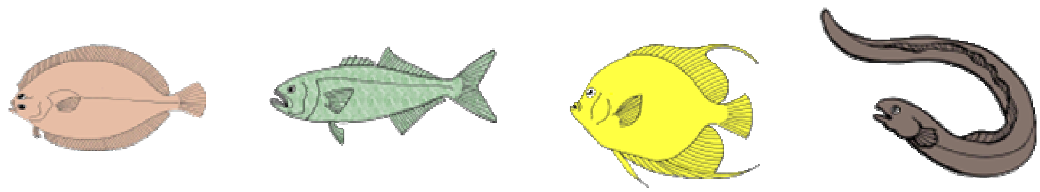
continued on next page

Task 4
Basic Fish Anatomy

This is a guided activity in which you will be shown a PowerPoint presentation that will provide you with the information that will help you learn basic fish identification in preparation for your field study at Rock Creek National Park.

Body Shape

The first step to fish identification is to determine the overall body shape of your fish. There are four common body shapes, as shown in the pictures below. On page 7 of your worksheet, **LABEL** each body shape**.**



Tall-bodied, laterally-compressed species like discus and angelfish are adapted to life in slow-moving waters. Slender, torpedo-shaped fish are better adapted to moving waters. Bottom-dwelling fish have flattened bellies and inferior mouths.

Body Parts

- As your teacher goes through the fish anatomy, complete your fish diagram on page 8 of your student worksheet packet. On the diagram,
  - **LABEL** the body part
  - **COLOR** the entire body part
- After you have labeled and color-coded the diagram of the fish, turn to the "Fish Body Part" chart on pages 9 and 10. This table gives an explanation of each part of the fish anatomy. **COLOR** in each box with same color you chose for your diagram.

Example: If you colored the dorsal fin blue, the box on the table that says "dorsal fin" on your diagram would also be blue.

continued on next page

Task 5
ID Your Fish

On pages 9 – 12 of your worksheet packet, you are going to **SKETCH** different fish that you are shown on the PowerPoint presentation.

For each specimen, you will be given **3 MINUTES TO DRAW** it. You will use your drawings to identify these fish later.

Note basic body shape and parts so that your sketches are useful for identification. Do not get too caught up in making a perfectly detailed drawing.

In the box labeled "Characteristics," **NOTE** important features of that fish that would help identify it (i.e., forked caudal fin, barbels present, etc.).

Slide #	Teacher Notes to Accompany PowerPoint Presentation The highlighted phrases in slides 38 – 47 are characteristics students should write in the "Characteristics" column on their worksheet. These will reinforce what fish parts will help students identify fish in the park.
1	Intro slide – This PowerPoint presentation will emphasize characteristics of fish that will be useful in helping students to identify fish on the Herring Highway field study. It covers the most common characteristics, but students may find other ways to identify fish that are helpful to them.
2	Body Shape - **4 Basic Body Shapes** • **Fusiform** – The basic body shape of most fish, with the head forming the bulk of the fish, and the body tapering towards the tail. – Examples: Fallfish, White Sucker • **Attenuated** – A body shape that is long and skinny with the width of the body similar along the length of the fish. – Examples: Eels, Lamprey • **Flattened** – Body shape where the fish are flattened dorso-ventrally, meaning from top to bottom like a pancake. No fish we hope to identify in Rock Creek have this shape. – Examples: Flounder, Stingray • **Compressed** – Body shape where the fish are flattened laterally or from side to side. – Examples: Bluegill, Pumpkinseed Sunfish
3	Slide of example fish (that does not resemble a fish that exists) without parts filled in.
4	Slide of example fish with **Jaw** highlighted
5	Mouth Shape – **4 Basic Jaw Shapes** • **A**: Jaws and mouth even, point straight ahead – Examples: American Eel, Tessellated Darter • **B**: Lower jaw extends beyond upper, mouth points upward – Examples: Blueback Herring, Alewife • **C**: Upper jaw extends beyond lower jaw, mouth points downward – Examples: White Sucker (with large sucker-like lips), Longnose Dace • **D** - Jawless fish have a ring-like sucker of sharp teeth instead of jaws

	– Examples: Sea Lamprey (pictured)
6	Slide of example fish with **Snout** highlighted

7	Snout Shape **– 3 Basic Snout Shapes**
	• **A**: The top example shows a fish with slightly declining snout
	    – Example: Spotfin Shiner
	• **B**: The middle example shows a fish with a flattened snout
	    – Example: Blueback Herring
	• **C**: The bottom is an example of a "blunted" snout
	    – Examples: Bluntnose Minnow, Gizzard Shad

8	Slide of example fish with **Eye** highlighted
9	Eye Size Compared to Body Size • The left fish has a relatively large eye when compared with its body size and other physical attributes. In Rock Creek, only the gizzard shad has an eye size that will be helpful for ID. • The fish to the right has a more typical sized eye when compared with its body size and its other physical attributes. Most fish in Rock Creek are like this.
10	Slide of example fish with **Dorsal Fin** highlighted
11	Dorsal Fin • Dorsal fins are used to keep the fish upright and to aid in turning. • Most fish in Rock Creek have dorsal fins like the Bluntnose Minnow (left picture) or the Gizzard Shad (right picture). • Dorsal fins can be helpful in identifying fish when they have features like the "spot" on the dorsal fin of the Bluntnose Minnow. • Some fish have two dorsal fins; one spiny and one soft. We will discuss that in later slides on fin rays and soft dorsal fins.
12	Slide of example fish with **Fin Spines** highlighted
13	Fin Spines • Fin spines are a type of fin ray that has evolved into a sharp point used for protection. • They can be found on the dorsal (left picture), anal, pectoral, or pelvic fins of fish. • Some species are able to extend their spines to keep them wedged into a hole or crevice (in Rock Creek an example would be the Yellow Bullhead), while others have spines that contain venom (there are no venomous species in Rock Creek). • Fin spines will be especially notable in the Sunfish and Darters, and care should be taken to avoid getting poked. • The Yellow Bullhead, like most fish in the catfish family, has a sharpened spine in its pectoral fin that can be very dangerous (pictured at right after removal from fish). Never handle Yellow Bullheads without ranger/educator assistance.
14	Slide of example fish with **Fin Rays** highlighted
15	Fin Rays **– 2 Basic Fin Ray Types** • Fin rays are bony projections into the fins of fish that add support and stability to the fins. • They come in two types: fin spines, which were described in the last slide (right picture) and soft fin rays (left picture). • Soft rays (usually referred to simply as rays) can be found in all of the fins of fish. • Many species are identified from other species by the number of rays on a given fin.
16	Slide of example fish with **Soft Dorsal Fin** highlighted

17	Soft Dorsal Fin **– 2 Basic Types of Soft Dorsal Fins** • Soft dorsal fins typically contain only rays and no spines. • Many fish do not have a soft dorsal fin. • **A.** Most fish in Rock Creek that have both a dorsal and a soft dorsal fin have the two fins arranged and separated like the Tessellated Darter (left picture). • **B.** A few fish, like the Pumpkinseed Sunfish pictured at the bottom right, have both a dorsal fin and a soft dorsal fin; and, though distinctly separate, they have evolved to have thin webbing that connects the two so that they look like one long fin.
18	Slide of example fish with **Adipose Fin** highlighted
19	Adipose Fin A small fleshy fin located behind the dorsal fin, but in front of the caudal fin. In Rock Creek an example would be the Yellow Bullhead (pictured).
20	Slide of example fish with **Lateral Line** highlighted
21	Lateral Lines • A lateral line appears as a horizontal series of dots or dashes along the length of a fish's body (pictured left). • The lateral line contains channels, hairs, and muscles that are able to sense vibrations in the water. • The ability to sense movement through vibrations in the water can help predators find food, and prey to escape predation. • The lateral line can be very obvious or it may be very hard to see. In a few fish this may be a helpful tool for identification. • For example Blueback Herring do not have lateral lines.
22	Slide of example fish with **Caudal Fin** highlighted

23	Caudal Fin **– Many Shapes of Caudal Fins Exist**
	• The caudal fin is the "tail" of the fish.
	• Used by most fish to power them through the water.
	• Comes in various shapes, which can help with identification.
	    • **A –** Yellow Bullhead
	    • **B –** Alewife
	    • **C** – Bluegill Sunfish

24	Slide of example fish with **Scales** highlighted
25	Scales **– Many Types of Scales Exist** • Scales make up the protective outer layer of most fish. • The fish of Rock Creek have what are called ctenoid scales (pictured both en masse and singularly at left). • Ctenoid scales grow with the fish and thus have growth rings. • The fish in the herring family, such as the Blueback Herring, Gizzard Shad, and Alewife, have modified scales on their belly that are called scutes (pictured at right are the scutes of a sturgeon to give an idea of what scutes look like). • These scutes form what feels like a dull saw blade running back towards the caudal fin and can be a helpful identifier. • Scales can be used to identify other fish as well. Fish in the shiner family have very distinctly diamond-shaped scales, unlike other fish we may find in Rock Creek.
26	Slide of example fish with **Anal Fin** highlighted
27	Anal Fin **– 2 Basic Types of Anal Fin** • The anal fin of a fish is an unpaired fin near the tail end of the fish. • The top picture shows the typical form of the anal fin, in this case that of the Fallfish. • The bottom picture shows an elongated form of the anal fin, in this case the

<table>
<tr><td></td><td>Blueback Herring.</td></tr>
<tr><td>28</td><td>Slide of example fish with Pectoral Fin highlighted</td></tr>
<tr><td>29</td><td>Pectoral Fins – Many Shapes of Pectoral Fins Exist
Pectoral fins are usually located along the side of a fish near the gills.
Examples of shapes: A – Pumpkinseed Sunfish, B – Gizzard Shad, and C – Longnose Dace.
More important than the shape of the fin is whether or not the fish has pectoral fins. One fish in Rock Creek, D - the Sea Lamprey, does not have pectoral fins.</td></tr>
<tr><td>30</td><td>Slide of example fish with Pelvic Fin highlighted</td></tr>
<tr><td>31</td><td>Pelvic Fins – 2 Locations for Pelvic Fins
Pelvic fins are usually small fins located in between the pectoral fins and the anal fin.
In Rock Creek, two species of fish lack pelvic fins: Sea Lampreys and American Eels.
Another helpful identification key with the pelvic fins is their location on the body of the fish: In the picture on the slide A. abdominal (like the Alewife) or B. thoracic (like the Tessellated Darter).</td></tr>
<tr><td>32</td><td>Slide of example fish with Gills highlighted (note: highlighted items are actually the opercula or gill covers)</td></tr>
<tr><td>33</td><td>Gills – 2 Basic Types of Gill Forms
Fish are able to obtain oxygen from the water by using their gills.
There are some species of fish that have simple openings along their body that exchange water.
Example: A. Sea Lamprey
Most species of fish have an operculum or gill cover that protects the delicate gills underneath as in picture B.
Example: Blueback Herring</td></tr>
<tr><td>34</td><td>Slide of example fish with Barbels highlighted</td></tr>
<tr><td>35</td><td>Barbels – 2 Basic Shapes of Barbels
Barbels are tactile (fish controls their movement) whisker-like organs, but they are not always visible, and some fish do not have them.
They contain many tastebuds and are used to locate food in murky conditions.
Barbels may be large like in the Catfish in A.
Example: Yellow Bullhead
Or they may be small, as in the Carp in B.
Example: Fallfish</td></tr>
<tr><td>36</td><td>Practice ID Drawing Activity with Pumpkinseed Sunfish</td></tr>
<tr><td>37</td><td>Fish ID Drawing Activity explanation</td></tr>
<tr><td>38</td><td>Specimen 1: White Sucker – Students should note the blunt snout with “sucker lips,” fusiform body shape, and abdominal pelvic fins.</td></tr>
<tr><td>39</td><td>Specimen 2: Tessellated Darter – Students should note the thoracic pelvic fins, separated, but present, soft dorsal fin, and fusiform body shape.</td></tr>
<tr><td>40</td><td>Specimen 3: American Eel – Students should note the elongated body, jaw shape (mainly that it does not have a circular, tooth-filled disc like that of a lamprey), and absence of pelvic fins.</td></tr>
<tr><td>41</td><td>Specimen 4: Bluntnose Minnow – Students should note the blunt snout, heavy lateral line, spot on dorsal fin, and abdominal pelvic fins.</td></tr>
<tr><td>42</td><td>Specimen 5: Yellow Bullhead – Students should note the long barbels, adipose fin, abdominal pelvic fins, and pectoral fin spine.</td></tr>
<tr><td>43</td><td>Specimen 6: Blueback Herring – Students should note jaw shape (that the lower jaw</td></tr>
</table>

	extends further out than the upper, causing the mouth to face up), lack of lateral line, eye-to-body size ratio, and overall body shape (that it lacks the prominent "hump" associated with Alewife.
44	Specimen 7: **Bluegill Sunfish –** Students should note thoracic pelvic fins, fused dorsal fins, black spot without orange color on gill cover, and overall blue-colored body (though color is not always the best identifier).
45	Specimen 8: **Blacknose Dace –** Students should note overhanging jaw shape, abdominal pelvic fins, and VERY heavy lateral line extending onto snout.
46	Specimen 9: **Sea Lamprey** – Students should note elongated body shape, lack of pelvic or pectoral fins, jaw shape (no real jaw, circular disc), and gill openings instead of covers.
47	Specimen 10: **Swallowtail Shiner –** Students should note abdominal pelvic fins, even jaw shape, lateral line that is dark and shaded but not contiguous to snout, and distinctly diamond shaped scales.

Prepare for Your "Herring Highway" Field Study

Dress Appropriately

- You should wear comfortable clothing that allows you to easily move, hike, bend, and climb. You may have to gather data in a wet and muddy environment, so choose clothes you don't mind getting wet and dirty.
- Dress for the weather. In cool weather, wear layers of clothing to keep warm in the early morning, but that you can remove later in the day or while working. If the forecast calls for possible rain, wear a waterproof jacket, hat, and shoes, and bring a plastic bag for materials.
- Even in warm weather, wear long pants and a long-sleeved shirt for protection from poison ivy.
- Expensive clothes and shoes are not appropriate for work in the outdoors, and wearing these expensive items will make you reluctant to engage in field studies.
- Do not wear skirts, shoes with high heels, or sandals.

Bring

- **LUNCH –** There will be no place to buy food. **Bring a bag lunch and plenty to drink**, preferably water. Pack your lunch and drinks in a backpack or bag that can be easily carried into and out of the park study site. Keeping in the ecology-minded spirit, make your lunch as trash free as possible. Avoid excessive packaging and reduce, reuse, and recycle. Remember, there is nothing beautiful about trash.
- **WATER –** The hotter the weather, the more you should bring to drink.
- **NOTEBOOK –** A notebook, clipboard, or journal to write in and on (waterproof is best, if possible)
- **PENCIL –** Something to write with (Pencils are best because they work when wet and are cheap to replace if lost.)
- **FISH ID INFORMATION –** Your worksheet with your fish drawings
- **POLARIZED SUNGLASSES –** If you have Polarized glasses, bring them. They will help you see fish in the water.

Park Stewardship

- No collecting of any type is permitted.
- Take only photographs/memories and leave only footprints.

Lesson 4. Swim for Your Life

Objective

To complete an interactive, online game and collect data that illustrate the hazards that anadromous fish encounter in their journey from spawning grounds to ocean and back to spawning grounds

Introduction

Over the course of time, species of anadromous fish that used to be very common have all but disappeared. There are many causes for the decline of these species. Over-harvesting has certainly affected fish populations. However, most fisheries biologists agree that the steady decline in water quality and resulting loss of spawning and wetland habitats during the early and middle part of the last century has had the most dramatic impact. The annual migration, or run, is still significant for the river herring. One can still see people gathering at bridges over creeks and along waterways in the early spring when the fish make their move upstream to begin again this timeless cycle of life.

About the Game

At www.bridgingthewatershed.org, you will find the "Swim for Your Life" interactive game that traces the natural history of the anadromous fish. In the game, these fish begin their lives as developing fish embryos contained within the egg, and then develop into larval fish, living and feeding in marshland nurseries. Later they move into the river and estuary to begin their journey to the ocean. Once in the ocean, they will require three or four years of growth to reach sexual maturity, whereupon they will begin the same migration their parents made, leaving the open ocean and entering coastal estuaries and rivers. Their upstream journey will eventually take them to the watersheds from which they originated. Once there, they will spawn to create a future generation and continuation of the cycle. The task is for two fish to return to their original spawning grounds to breed and continue their species.

Complete Online Game Board →

continued on next page

How Herring Reproduce

A player begins the game as fertilized river herring eggs left to chance by the adults. Gravid (pregnant) females lay eggs. A male fish accompanies the female to fertilize the eggs. A mature female can lay as many as 300,000 eggs. Typically, the female swims in a very tight circle over the gravel or sand bottom in the water near the bank in a sort of mating ritual. The male is usually on the outside of the circle, swimming next to the female. As the female releases the eggs, the male releases the milt or semen into the water at the same time. At the end of the mating ritual, the male and female depart, and the eggs are left to chance. As the eggs begin to float downstream, they will encounter perils, both natural and man-made.

How to Play the Game

One or two people can play the game. During the game, your school of fish will move through the watershed from the spawning grounds (upper left hand corner/start) to the ocean (upper right hand corner online, lower right hand corner on the board game) and back again. Your school starts out with 100,000 eggs. The fish may encounter perils that will reduce the number of fish. (You can learn more about each peril by clicking your mouse on the name of the peril.).

As you move through the game, **RECORD** information on the datasheet located on pages 16 – 18 of your worksheet booklet. After each turn, record the percent fish destroyed and number of fish remaining in your school. Also decide if the peril is natural or caused by humans, and whether it is unavoidable or preventable.

The goal is to have at least two fish return to the spawning grounds to reproduce again.

For Teachers: Explanations of Swim for Your Life Perils

Overview

The text below is taken from the callout boxes on the website game, Swim for Your Life, and is provided for teacher reference.

Spawning Ground

Flood: A storm can send a large discharge of water into streams that flow through urban and suburban areas. An abundance of impervious surfaces (roads, parking lots, sidewalks, and roofs from homes and businesses) do not allow water to be slowly absorbed back into the ground. This water usually enters storm drains that send the water into local streams. The increased volume of water will cause smaller streams to overrun their banks and wash animals, eggs, and stream nutrients out of their streambed. As the storm ends and the storm water recedes, many of the stream organisms are left outside of the stream where they may perish. While stream flooding occasionally occurs in natural ecosystems, the impact is usually far less severe. Forested land and natural meadows act like a sponge and absorb much of the water during a storm. The foliage of the plant communities slows the impact of the falling rain. The layers of decomposing vegetation on the floor of the forest and meadow soak up the excess water. The volume of water that makes its way to the stream during a storm is much less.

Toxic fluids: People often handle hazardous substances and materials daily. The simple act of draining fluids from automobiles and machinery can imperil the lives of stream organisms if the fluids are mishandled. Most of these substances are highly toxic, and, if allowed to simply drain onto the ground or street, they may enter a storm drain that empties into a stream. Such toxins can be devastating to immature organisms. A few drops of oil leaking from a car each day may seem harmless, but when a heavy rain lifts the oil from all the driveways in a large urban area and carries it into storm drains and streams, the results are magnified. It has been estimated that the amount of oil leaking from cars in a major urban area over the period of a year is equivalent to the amount of oil that leaked from the wreck of the Exxon Valdez oil tanker ship. Educating the public in proper disposal or prevention methods could eliminate most small toxic spills and leaks.

Acid rain: Acid rain is the consequence of large concentrations of sulfuric acid present in the atmosphere. The main source of these concentrations is the burning of high sulfur coal to produce electricity or operate industrial plants. As the coal is burned, gases and particles from the burning process enter the atmosphere in the form of sulfur dioxide gas and sulfur particulate matter. The gases and particles mix with other atmospheric gases and particles. Water vapor in the atmosphere at higher elevations will condense on the sulfur particulate materials and form water droplets, which can fall to earth as rain. The sulfur dioxide and particulate matter can affect the chemistry of water by changing the pH value of a lake, pond, or stream. Heavy concentrations of the pollutant may make the body of water more acidic. If the acidity reaches a certain threshold, organisms living in the body of water begin to die.

Soaring temperature: Water management areas are often built where rivers and streams flow through densely populated areas. They are usually built as a response to recurring floods caused by water that has nowhere to go but directly into the river or stream. In such water management areas, earthen levees and dikes are constructed to act as barriers between the land and the rivers or streams that swell during periods of high water. For maintenance purposes, there are no trees growing along the banks of such structures. The streams and rivers still serve as a habitat for organisms, but the habitat can suffer from the exposure to direct sunlight throughout the day. A sudden warm-up can send air and water temperatures soaring. When water temperature increases, the dissolved oxygen (DO) count decreases, causing certain aquatic organisms to die.

Silt: Sediment entering streams can be caused by a variety of human activities. For the past three centuries, bad agricultural practices have been one of the main causes. Plowing land near watersheds, without vegetative buffering zones to catch soil runoff during storms, was a common practice up until the middle of the twentieth century when the soil conservation service began to educate farmers about using better soil conservation practices. In urban areas, the main cause of sediment-loading in streams has been the stripping of vegetation at construction sites. When it rains, exposed soil or dirt from roadways is easily washed away through storm sewers and into the nearest stream. The sediment settles on submerged aquatic vegetation or on organisms living in a stream, often smothering them. Sometimes the sediment load in a stream is so heavy that it prevents light from reaching submerged aquatic vegetation. Without light, the plants are unable to produce food by photosynthesis.

Salt: In recent years, the need to keep roads passable under adverse winter conditions has led to the use of chemical agents to melt ice and snow. The most common chemical agent is sodium chloride or salt. The accumulated effect of these chemicals in small streams can have a negative impact on the organisms residing there. As with sediments, these chemical agents will wash away from the road surface, enter storm drains, and make their way into the watershed. All organisms have a threshold tolerance limit for exposure to chemicals. If the chemical concentration exceeds the threshold, they will die. Younger organisms are often more susceptible to chemicals. Concentrations of these chemicals are more likely to be highest at the end of the winter season or in the early spring before they are flushed out of the streams and diluted in the larger waterways. This is the most critical time for anadromous fish species since they enter the watershed for spawning at the end of winter or the beginning of spring.

Predators: In all ecosystems, there is competition for food. Many organisms take advantage of the life cycle of other organisms in order to guarantee their own survival. Many species, including humans, have become acquainted with the life cycle of potential food species and know to be in the spawning areas in order to take advantage of the abundance of potential food. Other aquatic organisms (other fish, crustaceans, aquatic insects, etc.) will eat the eggs of these fish. The fish lay such a large number of eggs, this natural predation is not detrimental to the survival of the fish unless it is combined with other circumstances causing additional losses.

Cattle in stream: Cattle and other livestock, if permitted to go directly into streams to obtain their water, can do much to disturb the stream bottom. They can trample and uproot submerged aquatic vegetation that can hold sediment in place. With the vegetation gone, the sediment from the stream bottom is free to be washed away during a storm. The very action of entering the stream and wading about can stir up the bottom and increase the turbidity of the water.

Favorable conditions: Many local communities have a growing awareness of the life cycles of organisms living around them. Some citizens have taken individual or group initiatives to begin to restore habitats that support these organisms. The types of projects and the amount of work involved can vary, but the effect of these types of initiatives benefits all. Projects can be simple efforts to help make more citizens aware of everyday actions and the possible consequences of these actions. Stenciling storm drains with the message, "WATERSHED DRAINAGE AREA," can help prevent the use of storm drains as receptacles for discarded motor oil, anti-freeze, or other toxic substances. Stream cleanups can do a great deal to enhance the habitat of a stream. Tree and shrub plantings along streams can do much to improve the habitat of watersheds as well. By improving the habitat of a watershed, the conditions that are favorable for the survival of the organisms living there are also improved.

Optimal conditions: Optimal conditions would include all of the environmental factors needed for successful egg hatching. The stream would have to be free of pollutants. The water would have to have favorable physical qualities such as adequate dissolved oxygen and correct temperatures for the development of the embryos in the eggs. Adult fish would need a good habitat in which to lay their eggs, one in which the eggs would be safe from attack by predators. The stream would have to be able to carry excess water from storms without running outside of its banks, and the stream also would have be free of too much silt and soil. Such optimal conditions were once common throughout most watersheds. In some rare instances, these conditions still exist naturally; in many places, these conditions could be restored if people would take the initiative to learn what needs to be done and implement projects and programs to return streams to their natural state.

Stream Perils

Lack of food and cover: Sediments usually accumulate in areas where streams empty into a river. These areas are shallower than the main channel of the river and can become marshland habitats. Both submerged and emergent aquatic plants, which form the basis of a food chain, can be found there. Marsh habitats often serve as nurseries for smaller fish species and larval fish, providing them with nutrient resources and a safe place to hide from predators. If too much sediment enters a stream due to a natural event, human activity, or a combination of natural and human actions, it can accumulate at the point where the stream enters the river. The abundance of sediment will choke and smother the marsh habitat.

With food resources drastically reduced and fewer places to hide from predators, populations of small fish species and larval fish are at greater peril for survival.

Bridge construction: Any form of construction imposed on a natural ecosystem can potentially have a negative impact. Most construction involves the permanent or temporary removal of some habitat within the construction zone. The greatest impact is at the time of the construction project, particularly to the organisms living in the habitat at that time. If the project continues over a period of several years, it can cause damage with long-term consequences and an expensive, complicated recovery process. If damage does occur and recovery is slow, organism populations will also be slow to recover.

Pesticides: Larval fish are very sensitive to chemicals, more so than adult fish. Even if the larval fish survive exposure to poisons or other harmful chemicals, damage could be done to their still-developing organ systems. Chemical agents like pesticides can enter a watershed from a variety of sources. A business or individual could deliberately or accidentally dump chemicals into a storm drain or stream. The improper use or application of pesticides on agricultural land, commercial land enterprises (golf courses, amusement parks), public lands (national, state, county, and city parks and recreation areas), and private, residential property can result in these toxins entering a watershed.

Chlorinated water: Water treatment facilities use chlorine as an antibacterial agent to destroy microbes in wastewater. Before sending the treated water back into a river, they usually remove the chlorine. Some cities have a combined sewer and storm water system that brings wastewater to a treatment plant. During periods of heavy rain, the volume of water is so great that the wastewater treatment plant cannot properly treat the water. Since the overflow of water will not receive the regular treatment process, wastewater engineers will add chlorine as the minimal treatment to kill potentially harmful bacteria. In such cases, the chlorine will not be removed before the water returns to the natural system, resulting in an excess amount of chlorinated water entering the watershed. The chlorine can kill many species of aquatic organisms, including small fish species and larval fish.

Microbe attack: All living things are vulnerable to attack from microorganisms. Younger organisms are often more susceptible because they have not had time to build up resistance to these potentially lethal microbes. Healthy, older organisms are less vulnerable to infection from such pathogens. However, when organisms are stressed due to rapid environmental changes or lack of food, microbes can more easily infect them. Outbreaks of disease-carrying pathogens can be caused by a variety of circumstances. The decomposing bodies of larger animals killed in floods can introduce dangerous bacteria to the watershed. Direct application of untreated animal wastes to agricultural land also can result in the introduction of pathogens to a watershed. Inadequate water treatment facilities may have to send some untreated wastewater back into a river during a period of heavy rainfall.

Low dissolved oxygen: Aquatic organisms receive oxygen needed for metabolic processes from dissolved oxygen (DO) in the water. Fish obtain the oxygen by passing water containing DO over their gills. DO in water can vary depending on the physical environmental conditions in a watershed. Cold water can hold more DO than warm water. DO levels can change during seasonal temperature changes. Small bodies of water, providing they have tree-lined banks, will have cool water even during warm summer periods and can maintain levels of DO to meet the needs of organisms living in the water. If there are no trees along a stream, the water can warm up and lose dissolved oxygen. DO can enter the water at places where it spills over rocks and at waterfalls or other areas of rapid water movement. Sluggish, slow-moving streams tend to have less DO than fast-flowing streams with water spillway areas.

Fertilizers: Biological factors can create unhealthy situations for aquatic organisms. Algae living in water and sustained by the right level of nutrients can increase the dissolved oxygen (DO) in the water. However, when a lake, stream, or river receives too many nutrients (phosphorus or nitrogen from chemical fertilizers entering the watershed), these nutrients can over-stimulate the growth of the algae. If the algae bloom becomes excessive, algae at the surface can block light from the algae below, which then begins to die. Bacteria use the DO in the water to decompose the dead algae. Eventually DO levels fall dramatically. This has a detrimental effect on the other organisms living in the water.

Predators: Predation is natural in any ecosystem. Such predator-prey relationships exist to maintain a balance or equilibrium within the ecosystem. This keeps any one species from overwhelming a habitat and potentially changing the balance. Anadromous fish have high reproductive rates because they face many natural risks and perils in the ecosystems where they live. Only a few of the offspring will need to survive to adulthood and reproduce. The survival of many of the other organisms in the ecosystem is equally dependent on the high reproductive rate of these fish.

Habitat restoration: In some areas, people have begun to understand the value of wetland habitats to the overall health of a watershed ecosystem. Old attitudes that once caused people to think of wetlands as wasted space are changing. Such places are now valued as nutrient factories and nurseries for many aquatic organisms. This has led to individual and group-sponsored initiatives to restore these habitats in places where they once existed or where they are threatened. People now know what must be done to keep rivers and streams full of fish, waterfowl, and other desired aquatic life forms. The restoration and preservation of wetland habitats is one sure way to guarantee a better and healthier watershed ecosystem.

Conservation legislation: State legislatures have reacted to pressures from both the public and conservation lobbyist organizations to protect selected wetland areas from development or damage from nearby development. In many states, legislators have begun to pass laws to set aside these areas for special consideration. When such areas are preserved in their natural state, the species of organisms that coevolved within that environment will have a better chance of survival. A watershed area that has been badly damaged cannot be totally returned to its original state. But it is not too late to preserve existing areas that have been less impacted by human activity.

River Perils

Power plant: Power-generating plants are usually located next to rivers because they need massive volumes of water to cool equipment. These plants often have large pipes that intake and discharge water. Intake pipes typically have bar screens to keep unwanted material from entering the system. Larger forms of aquatic life can be drawn up against the bar screen and held in place by the intake flow. Smaller forms can pass through the screens but will undergo life-threatening stresses later as they move through the water circulation system that cools the turbines and generators of the power plant. Some modern plants have cooling towers that return the water to the river at nearly the same temperature that it was removed. But older plants are likely to discharge the warm water directly back into the river. The warmer water, lower in dissolved oxygen, can cause stress to aquatic life in the area of the discharge pipe.

Low dissolved oxygen: Juvenile fish are moving through the estuary on their journey to the ocean during the late summer. Some risks are present during this season that would not necessarily be there during other seasons. Warm, dry weather can cause the river and estuary to have a high concentration of nutrients. These conditions lead to algae blooms that can form dense mats on the surface, blocking sunlight to submerged plant life and to submerged algae. Lack of light causes these plants to die and accumulate on the bottom. Then bacteria begin to decompose the accumulated biomass. The bacteria breaking down the vegetation deplete the dissolved oxygen in the water. Some sections of the river can have dissolved oxygen levels that are so low, the fish die on a massive scale.

Petroleum spill: Petroleum-based chemical spills are dangerous to aquatic organisms for a variety of reasons. Direct contact with concentrated petroleum chemicals can kill many forms of aquatic life. Partial exposure to diluted petroleum chemicals can cause paralysis, making the exposed organism vulnerable. It can also interfere with normal physiological processes such as extracting dissolved oxygen from the water through the gills. Petroleum spills can occur in a single catastrophic event or slowly over time. A vessel transporting petroleum products can sink or have an accident, causing a spill in a large body of water. An onshore pipeline transporting petroleum can rupture, causing a spill that will enter the watershed at the point of the pipe breakage, eventually making its way to the larger body of water. Automobiles driving on road surfaces leak small amounts of oil, but the cumulative effect of all the cars over time leads to as much oil entering the watershed as a major oil spill during a single event.

Predators: The late summer season is the time of year when many larger predatory fish are in the river and estuary in search of food. Many of these larger fish are dependent upon the anadromous fish life cycle for their own survival. Striped Bass and Bluefish are voracious predators of many juvenile fish species in the herring family. In a balanced ecosystem, such predation is a limiting factor on the biotic potential of these otherwise abundant fish. Every organism has the potential to overwhelm the environment if there are no limiting factors to keep a balance in the ecosystem.

Lack of food: If a species increased in numbers without any limiting factors, the unchecked population could throw the ecosystem out of balance. Lack of sufficient food is a limiting factor that can keep a population in check. There is constant competition for food resources in any ecosystem. If a population is out-competed for scarce food resources, it will starve, with the weakest members dying first. In a watershed, the availability of food resources can vary depending upon recent events or seasonal changes. An area may have ample food resources one week and no resources the following week. A population of herring-type fish must continue on its journey to the open sea, whether it finds sufficient food or not.

Storm surge: When juvenile fish swim close to the shoreline of a river or estuary to find cover and food among the shallow water submerged plants, they can be washed ashore during a sudden, strong storm. A surge of water can wash over beaches and banks at the edge of the river or estuary, sometimes accumulating in low areas with no access back into the river or estuary. Aquatic organisms that get washed into these areas become trapped and can die as water evaporates from these areas.

Gull attack: Many species of birds are dependent upon small juvenile fish as a food source. Herring gulls are one such predatory bird species. They often travel in large flocks and can easily spot a large school of fish swimming close to the surface in open water. There are times when these juvenile fish must move through open water during their journey to the sea. They are driven to the surface by fish predators from below or to search for food. If gulls or other predatory birds spot them at the surface, an attack can occur, resulting in a loss in the fish population.

Leeches: Populations of a particular species are kept in check by such limiting factors as natural predation or lack of food. Parasites like leeches are another type of limiting factor. Though leeches will not usually cause the direct death of the host species, they can weaken the animal, thus causing the animal to become vulnerable to other predators. If a parasite infestation is large enough, it can contribute to the direct death of the host species.

Low predation: Under normal conditions, predation is necessary to maintain a balance in an ecosystem. If a population of organisms is very large, predators can help to remove the weak and sick individuals. A population with adequate food and protective cover will have less vulnerable members than one with a poor diet and lack of good cover. There are many variables that can play a role in how successful a population will be during the journey to the open sea.

Optimal conditions: Although highly unusual, it is theoretically possible that a population of juvenile fish could survive intact in a particular part of its journey. If the fish could avoid all potential hazards and find adequate food and cover during the journey, the entire population could survive.

Ocean Perils

Purse seines: Maturing anadromous fish entering the open ocean are subject to many forms of attempted capture by humans. Commercial fishermen want the fish to sell for food and for a wide range of other products such as fish oil that can be used in paints, cosmetics and medicines. In most instances, very large quantities must be harvested in order to make the effort economically worthwhile. People have devised many types of fishing apparatus that enable them to capture large numbers of fish at one time. One such device is a type of net called a purse seine that encircles a school of fish and captures most of them.

Lack of food: Fish in the open sea not only face predation, but must continue to seek food resources to further their growth and development. Fish that are unable to find enough food can weaken and become more susceptible to disease or more easily preyed upon by other species. Availability of food resources can be governed by competition between members of the same species or with other species.

Haul seines: Commercial fishermen attempting to capture large numbers of fish might use a type of net called a haul seine. One end of a net is released from the main fishing boat. A smaller boat takes the other end of the net and stretches the entire net to the end of its length. It then returns to the larger boat in a semicircular path, bringing the end of the net back and hooking the net to a winch on the main boat. The winch hauls the net back on board the larger boat. Fish that were encircled and trapped in the net are brought on board and removed from the net. The captured fish might be sold to commercial lobster and crab fishermen for bait in their crab and lobster pots.

Floating gill nets: Commercial fishermen have traditionally used an entrapment device called floating gill nets. Long lengths of flat nets with weights on the bottom and floats on the top are released into the water and allowed to drift over areas where large schools of fish have been spotted. The fish swim head-first into the net, but the openings in the net are too small to allow the entire body to pass through. If the fish tries to back out of the net, their gill cover or operculum will get entangled in the net and the fish will be trapped. After the nets have drifted in an area for several hours, they are brought back on board the boat and emptied of their catch. The fish might be sold to plants that will process them into kippers (canned fish), pickled fish, smoked fish, or salted fish, all for human consumption.

Trawl net: A trawl net is one of many devices used by commercial fishermen to trap large numbers of fish. A trawl net resembles a large basket when it is lowered into the water. It is attached to ropes or cables, which in turn are attached to a winch. The trawl net is dragged behind the boat over an area where fish are thought to be. Eventually, the net is hauled back onto the boat and emptied of its catch. The fish might be dried and ground into a product called fishmeal. Fishmeal is used as a protein supplement in food that is fed to poultry and hogs raised for human consumption.

Tuna attack: Many of the larger ocean fish that humans are accustomed to eating such as tuna are dependent upon smaller species of fish as their food source. Declines in population of the smaller fish would have an immediate effect on populations of larger fish.

Bluefish attack: Seasonal sport fish that many people like to catch for fun or food are dependent on members of the herring family for food. The members of the herring family are primary consumers, feeding mostly on microscopic, photosynthetic plankton and some zooplankton. They are eaten by larger fish, which may eventually be eaten by even larger marine life and by humans. Because of their position in the food pyramid, herring fish are more abundant than the larger fish. As long as herring remain abundant, there will be enough food to support populations of larger fish. Declines in numbers of herring fish would reverberate throughout the watershed ecosystem.

Bird attack: Many predatory animals, including large fish, are dependent upon the members of the herring family. Species of birds like gulls and terns have learned to prey upon the abundance of herring-type fish. They typically watch for large schools of fish to be driven to the surface by pursuing predator fish. The birds then swoop down or dive into the water to capture the fish. The birds represent second or third level consumers in a food pyramid. Like other predators, they depend on a plentiful supply of first level consumers to provide their food resources.

Favorable conditions: Healthy ecosystems maintain a near perfect balance between all of the different trophic or feeding levels that occur within the ecosystem. If a population is healthy and competition for food resources is not too great, the population's survival rate can be high. Healthy populations are stronger and also better able to escape natural predators.

Optimal conditions: Total survivability of a population is possible but not highly likely. Most natural ecosystems have limiting factors that keep population growth in check. When ecosystems are out of balance, due to natural or human-caused changes, a population of a particular species may temporarily have some limiting factors removed, resulting in an unnatural increase in numbers. Over-harvesting of larger sport fish might remove a natural predator. A ban on commercial fishing to restore depleted fish populations would remove a human predator. Such actions would cause the herring fish population to temporarily increase or remain intact. An unchecked population could overwhelm the ecosystem for a while and would eventually consume all of the existing food. At that time, the limiting factor of starvation would bring the population back under control.

River Perils

Pound nets: Adult fish that begin the return journey to the spawning grounds in the early spring often hug the coastline and shallow areas of the lower bays and estuaries during this season. Humans have long been aware of the behavior of the fish and have created a variety of entrapment devices that enable them to capture large numbers of the fish for commercial purposes. Pound nets are used in conjunction with barriers from the shore that may extend hundreds of yards into the bay or river. When a school of fish encounters the barrier, it follows the barrier out into deeper water to find a way around it. At the end of the barrier are openings that lead into enclosures that trap the fish. Later fishermen pull their boats next to the enclosure and remove the fish. Such fish will then be sold, perhaps to be made into smoked or salted fish for human consumption.

Staked gill net: Commercial fishermen use many entrapment devices to catch large numbers of fish. One such device is the staked gill net, a long, flat net held in place by wooden stakes. It is usually stretched out in shallow water areas near the shoreline, where the fish are likely to pass on their journey up the estuary. The openings on the net are large enough to permit the head or front portion of the fish to pass through the opening. The middle section of the fish is too wide to get through the net. As the fish tries to back out of the net, the operculum or gill cover on the fish will get caught and prevent the fish from freeing itself. Fishermen lift the nets from the water and pull the fish out of the nets. Such fish could then be sold for human consumption or perhaps to a nearby aquarium needing food for its seals, porpoises, sharks, and other large fish.

Wrong turn: A fork in a river can pose a problem for adult fish swimming upstream to spawn. One wrong turn could lead to a dam or other obstruction that would block the fish's way. Dams in rivers have been blamed as one of the principle reasons for the decline in many anadromous fish species. This human-made obstruction serves a beneficial purpose for people but prevents fish that inhabit the river from having access to upper watershed spawning areas. Fish are sometimes able to get beyond the dams by using fish-friendly devices like fish ladders. However, the dam itself can have a degrading effect on the spawning habitat that was once swiftly moving, highly oxygenated water. Often, when migrating fish encounter obstructions that interfere with the return to their place of origin, they do not complete the journey. If they spawn, they may lay their eggs to hatch and develop in a less favorable habitat.

Haul seine: In upper reaches of the rivers where there is a narrowing of the watershed, commercial fishermen use an entrapment device called a haul seine. It is a net that may be several hundred yards long. One end of the net can be kept on the shoreline while a boat is used to pull the other end of the net out into the river. The net is stretched out and then brought back to the shore in a semicircular path and attached to a winch. The winch will pull the entire net back to the shoreline. Any fish that were encircled and trapped by the net are brought onto the shore as the winch pulls the net in. The fish are gathered and processed for a commercial use.

Predator fish: Many predatory fish take advantage of the spring migration of anadromous fish. The presence and abundance of large schools of migrating fish makes finding food easy and capture less difficult. Many of the sport fish species that people like to eat, like Bluefish and Striped Bass, rely on the spring fish migrations for food resources.

Swimming off course: Violent spring storms can cause floods that disorient the fish in the murky water or create strong currents that can take the fish off course from their journey. The fish may end up within marshlands that can be a maze of channels and small waterways. When the fish become confused, they may not find their way back to the main channel to complete their journey.

Bird predators: When migrating fish follow close to the shoreline and stay in shallower water, they are more vulnerable to attack by flocks of gulls and terns. These birds have learned to know when the spawning runs occur and how to take advantage of the easy and available food resources necessary for their survival.

Changing conditions: Heavy rainfall in mountains hundreds of miles away from the estuary can have negative consequences on the journeying fish. If timber harvesting goes on unabated in the mountain regions of the watershed, there is less vegetation to absorb and stem the flow of rainfall, thus allowing a greater volume of water to enter the watershed. The cumulative impact of this greater discharge of water into the river system can be devastating to organisms living in the watershed and very disruptive to their natural cycles.

Fishing regulations: Fishing regulations and enforcement have done a great deal to prevent over-harvesting and depletion of natural resources. Regulations are established to provide some guarantees that a resource will not be completely decimated. The number of traps that commercial fishermen can set is limited by these regulations. The lengths of the nets the fishermen use are also limited. Seasons for harvest are established so that species are not taken year around or during critical periods of their life cycle. Very often, the fees derived from the licensing side of regulation are designated for use in the improvement of the habitat of the species being regulated.

Optimal conditions: In order for a population of organisms to survive intact in a particular part of its life cycle, some of the natural limiting factors in the ecosystem would have to be suspended. When ecosystems are out of balance due to natural or human-caused changes that remove a predator from the system or cause some other interference, a population of a particular species may temporarily increase in size. Such unchecked population growth will soon deplete food resources. Then the limiting factor of starvation will bring the population back under control.

Stream Perils

Stream blockage: Deforestation can cause stream blockage in several ways. The logging itself can leave excessive debris that keeps the fish from reaching their destination. In areas where intensive logging has taken place, soil is more likely to erode into the spawning streams. This sediment can fill in a stream to the point that it is too shallow for medium-sized fish like herring to swim. Spawning streams that go through developed areas where people live may also be subject to blockages created by trash and debris entering the stream directly or through the storm drains.

Changing conditions: Stream changes can occur for many reasons. The change might be the result of citizen complaints about flooding in residential areas. In such a case, the local municipality might decide to widen the streambed or to give the stream a concrete bottom. Either of these techniques might relieve the flooding in the immediate stream vicinity, but they would likely destroy any fish-spawning area and still would not address the root cause of the flooding. Over-development in and around the watershed, and the creation of abundant impermeable surface areas, are the real causes of flooding in the watershed.

Stream alterations: Sometimes sections of streams are actually buried or diverted through large concrete pipes in order to make more space available for construction purposes or to provide easier access to a development site. Aquatic organisms familiar with streams in open terrain environments are confused by the sudden appearance of such structures. Problems occur particularly at the discharge area of the pipe where the stream bottom may have been deepened, causing a change in elevation. If the end of the pipe is elevated above the stream flow, fish might have trouble reaching their spawning destination in the stream.

Anglers: Local citizens, who like to catch fish for fun and for food, frequent small streams during the spawning season. They will line the banks of narrow spawning streams to snag the abundant fish with gang or treble hooks or catch them in dipping nets placed in areas of the stream where the fish must pass in order to make their way upstream. The spawning run is an opportunity to obtain a large quantity of food very inexpensively. Fish can be caught while they are abundant and frozen or preserved in salt for later use.

Sediment: Some spawning streams will flow through land that is used for agricultural purposes. Unless the land is properly managed and soil conservation measures are in place, a severe spring storm that coincides with the plowing of fields can cause large amounts of topsoil and silt to wash into the stream, clogging access to spawning areas.

Sport fisherman: Sport fishermen like to take advantage of the easy catches in a spawning stream. They may use shad darts and snag or gang hooks to capture fish. Such fishermen usually have to obtain a sport-fishing license and have to follow regulations that govern how many fish they can catch in a day. However, the number of people that participate in recreational fishing is increasing.

Chemical poisoning: Landfills within the area of a watershed present some special hazards to aquatic organisms. A substance called leachate can collect in the bottom of a landfill. Leachate is a mixture of water and numerous household chemicals derived from cleaning agents, paints, food substances, medicines, oil, and other materials people throw away in their trash. The leachate can contain some very toxic substances and can kill sensitive organisms. Sometimes this leachate can leak through cracks in the landfill liner and make its way into a nearby stream. This leakage can cause a chemical contamination of the stream that may have a detrimental effect on the animals living in the stream.

Predators: Both humans and animals take advantage of the spring spawning cycle of anadromous fish. Natural predators such as raccoons, minks, and river otters will enter the streams during the spawning runs, capturing the abundant herring-type fish to eat.

High citizen awareness: Some people are becoming more aware of the plight of some natural waterways and the living things that are so much a part of the watershed ecosystem. As people develop an understanding of the life cycles of the organisms in these habitats, they are able to identify areas of concern. More importantly, this knowledge will sometimes lead to action. Local citizens, businesses, and government may work together to seek ways in which they can restore a component of a degraded ecosystem such as a spawning stream blocked by a dam. Aware citizens can bring the problem to the attention of those in business and government who can solve the problem.

Optimal conditions: Schools and student groups can play a big part in improving the watershed environment. Some school groups adopt local streams or sections of a riverfront. They remove materials from the stream or river that would be impediments to fish moving upstream. They plant trees along the banks of the stream and stabilize badly eroded areas. Students have restored streams or sections of streams to provide more habitats for spawning. Such efforts contribute to the recovery of the watershed ecosystem as a whole.