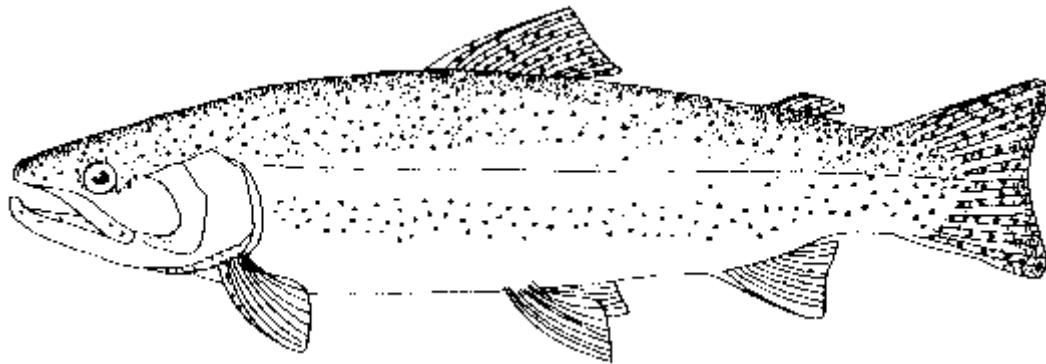


Coldwater Conservation Education Guide



By Margaret Sherriffs and Duncan Blair
Trout Unlimited 2002



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Curriculum written by Margaret Sherriffs and Duncan Blair

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Activity Descriptions

Activity #1, Stream Sense

p. 9

An activity for a field trip to a stream or lake, **Stream Sense** is designed to cultivate close observation and analogy-drawing skills. It hones the senses that are at the root of biological investigation by having students use all of their senses to observe a stream.

Activity #2, Connect the Critters

p. 13

In this indoor activity, students are provided with a handout showing pictures of a number of plants and animals that might make up an ecosystem. They are asked to draw arrows showing the flow of food or energy through the ecosystem.

Activity #3, Water Cycle Fill-In

p. 18

In this indoor activity, students are provided with a picture of different elements of the hydrological cycle and asked to draw in the different pathways that water could take. Indoor activity.

Activity #4, Create a Watershed

p. 21

This indoor activity is part art project and part science project. It lets students create their own visual aid to help understand how water moves in a watershed.

Activity #5: Sum of the Parts

p. 22

This indoor activity illustrates the downstream effects of water pollution and will facilitate discussion of some of the social and political issues that surround water use. It asks students to “develop” a piece of riparian land and role-play different users of the resource.

Activity #6: Just Passing Through

p. 24

This active, outdoor activity illustrates the role of plants in a watershed and shows what happens when they are removed.

Activity #7, Insect Life Stages Fill-In

p. 33

This indoor activity requires students to label corresponding body parts on diagrams of nymph and adult mayflies. It reinforces the chapter’s core ideas, adaptation and metamorphosis.

Activity #8, Stream Safari

p. 35

In this field trip to a stream, students carefully inventory features of the aquatic environment and collect aquatic invertebrates. Students will learn about biology, collection techniques, and the insects that compose most of the trout diet.

Activity #9, Water Quality Bioassessment **p. 39**

Students collect and analyze samples of aquatic invertebrates in order to assess water quality. This activity teaches students to recognize insects that are common trout foods and teaches biology skills like using a dichotomous key. This activity includes outdoor collection and indoor analysis.

Activity #10, Trout Fill-In **p. 51**

In this indoor activity, students label a drawing of a trout to learn basic anatomical definitions.

Activity #11, Color a Trout **p. 53**

In this indoor activity, students color in a line drawing of a trout. This activity can be used to teach markings of different species, or it can just be for fun.

Activity #12, Which Side are You on? **p. 55**

This activity can be used indoors or out. It helps students compare and contrast the lateral line with the human sense of hearing, and to apply students' new knowledge of trout biology to fishing tactics.

Activity #13, Salmon Farming Debate **p. 57**

This indoor activity for more advanced students asks students to look at different sides of the controversy over salmon farming. The teacher can choose the level of research required and assign a different role to each student before the class debate.

Activity #14, Find the Trout **p. 60**

Students can do this indoor activity before or after visiting a stream. They are asked to name the features of a stretch of water and predict where trout will be. It reinforces the vocabulary used to describe water and principles of trout behavior.

Activity #15, Color me a Watershed **p. 73**

This indoor activity for more advanced students demonstrates how maps are used to demonstrate land use changes over time. Once students know a bit about NPS pollution, it is easy for them to see what different land uses mean for a watershed.

Activity #16, Taking Account of Water **p. 101**

In this indoor activity, students estimate their daily water consumption before keeping track of it for 24 hours and calculating their actual daily water use. The results are used to initiate a discussion about ways of conserving water.

Activity #17, What's Causing What's Wrong? **P. 105**

This advanced activity requires a field trip to a library or media resource center. Once students have discovered a threat to a watershed, the research they do in this activity helps them figure out exactly what policies and practices are contributing to the problem.

Chapter 1, Introduction

Purpose

Welcome to the Trout Unlimited *Coldwater Conservation Education Guide*. This guide is a resource for TU members who want to teach the principles of coldwater conservation. The conservation content here is designed to complement fly fishing instruction. As you teach fly fishing skills, it is also important to teach (1) the science behind healthy trout habitats, and (2) the ways humans can positively or negatively affect such habitats.

How to Use this Guide

Ease of use and flexibility were our primary concerns when we developed the format of this guide. Each section is a set of related ideas that can stand on its own, as a single workshop or class period. Most sections are accompanied by one or more activities that develop and reinforce the ideas in the text. The activities can stand on their own, without the text, so that they can be used if you have written your own lectures or are primarily using guest speakers. Chapters are organized so that later subjects build upon earlier ones, but each is complete enough that it can stand on its own. For example, **Trout Behavior & Biology** is not a prerequisite for **Reading the Stream**, but teaching **Behavior and Biology** first will certainly enhance the second lesson.

Every section contains some or all of the following components:

- **New Ideas:** these are the “topic headings” within a section. They are written for the teacher, but read much as a lecture might. Important terms are in **bold** text and are defined in the **Glossary** and can serve as an outline if you prefer to lecture from one.
- **Handouts:** these should be photocopied, one copy per student
- **Overheads:** to be duplicated on an overhead transparency for review with the class
- **Activities:** referring to the page listed will give you instructions for leading the class through the activity. Some activities contain handouts that must be duplicated for each student. Each contains guidelines for the time the activity will take and the age group for which it is most appropriate.
- **Discussion:** this contains questions for review, discussion, and debate.
- **Extensions:** this contains suggestions for additional topics, discussions, or activities.
- **References:** most sections contain references and URLs for additional resources (information and activities) within the text and under this heading.

The **Schedules and Field Days** section lists sample schedules for day-long, week long, and semester-long programs. They show how conservation topics might track with a fly fishing skills curriculum.

Thank you for volunteering your time to this program. Please contact the TU national office [trout@tu.org or (703) 284-9420] and ask for the Youth Coordinator if we can be of service, or if you would like to comment on this guide.

Best wishes and happy fishing.

Chapter 2, Ecological Concepts

Use with fishing skills **FLY TYING** and **READING THE WATER**.

New Ideas

- **Competition**
- **Picturing Ecosystems**
 - o **Handout or Overhead: Three Ways of Looking at an Ecosystem, p. 7**

Activities

Activity #1: Stream Sense, p. 9

Activity #2: Connect the Critters, p. 11

- o **Handout: Connect the Critters, p. 13**

Introduction

A basic understanding of ecology will make conservation education much more interesting and productive. Scientific research, especially in biology, always begins with careful observation and the question, “why?” **Activity #1, Stream Sense (p. 9)**, is designed to cultivate close observation and analogy-drawing skills. It hones the senses that are at the root of biological investigation. Ecological concepts are best taught the same way.

Teaching Tips

Use students’ own observations and insights to fuel discovery and discussion. This section includes a few important definitions, but once students understand them, it is intuitive and fun.

Some Definitions

Ecology is the study of organisms (living things) and their environments. It is concerned with **ecosystems, populations** of interacting organisms and their **habitats**. The **population** is the basic functional unit of an ecosystem, a group of organisms of the same species living together in a specific area. **Habitat** means “home.” It is the physical space in which an organism lives, both its non-living and living elements. For example, a rainbow trout might live in a particular stretch of a freestone stream. Its habitat includes the water, the rocks, and the fallen tree that creates the eddy from which it feeds. It might share the habitat with other organisms, like weeds or diving beetles.

Competition

Ecological niche includes habitat, but is a more complete description of an organism’s lifestyle. Niche is made up of habitat, food, climate, and behavioral factors, like what time of day something feeds or when its mating season is. Many species can share the same habitat, but in a given habitat, each species has a unique niche. When different organisms’ niches overlap, e.g. when rainbow trout are introduced into golden trout habitat, they **compete** for resources. Sometimes animals compete by physically

fighting. Other times, one species is just better at exploiting the resource than the other, so that the weaker species cannot reproduce as much.

Two species with *partially* overlapping niches can live in the same habitat, even if they eat the same things. Two species whose niches *completely* overlap cannot coexist; one will always be driven to extinction. Brown and rainbow trout often coexist in a single stream habitat, but they behave differently. Compared to rainbow trout, browns tend to choose **lies** (sites from which to feed) that are closer to the bottom of the stream, and in slower-flowing water. (In addition to being a good example of partial niche overlap, this is part of the reason that brown trout are more difficult to catch than rainbows are.) In contrast, golden trout are in big trouble, because rainbow trout have been introduced to their habitat in the Little Kern River drainage. Because of geological barriers, golden trout evolved without competition from other trout species. Now competition (plus hybridization) with introduced rainbow trout is such a problem that the Little Kern Golden Trout is endangered. Rainbow trout are very closely related to golden trout, and their niches overlap completely. The two species cannot coexist forever.

The preceding examples were all types of **interspecific competition**, competition between different species. Organisms also experience **intraspecific competition**, competition with members of their own species. There is intraspecific competition for food, like farm animals shoving to get to a trough, but the phenomenon is often most apparent when animals are mating. Every male trout wants to mate as many times as possible, but there is only about 1 female per male, so males often have physical confrontations to determine who will get to mate with a female who has prepared a redd (nest). (See **Ch. 5, Trout Behavior and Biology**.)

Picturing Ecosystems

Use the handout **Three Ways of Describing an Ecosystem (p. 7)** to illustrate the terms in this section.

Competition is one important type of interaction. Another very important one is consumption, or feeding. We often describe organisms as **producers** and **consumers**, or as **predators** and **prey**. A producer is an organism that creates its own food (chemical energy) from the sun (light energy). Plants, like algae and green plants, are producers. Primary consumers get energy by eating producers. A predator is a secondary consumer, one that eats other consumers. We use the idea of a **food chain** to describe the way these relationships fit together. For example, algae (the producer) grows turns sunlight into carbohydrate, which, is eaten by a caddis larva (the primary consumer). The caddis is eaten by a damselfly (the secondary consumer), which is in turn eaten by a minnow, which is finally eaten by a trout (the top, or climax, consumer).

Organisms are linked together by food chains, and these chains get woven into **food webs**. Even though there are a few cases in which one organism can only eat a single species, those restricted interactions get drawn into more complicated relationships. That's not as boring as it sounds. For example, sea urchins can only eat one kind of brown kelp, but they get eaten by both sea otters and sea turtles, which both eat all sorts of different things. Students can play **Activity #2, Connect the Critters (11)**, to see how convoluted things can get.

Another way of picturing the interactions between organisms is with an **energy pyramid**. It is obvious that when one organism eats another, there's a transfer of matter,

but the real story, a hidden story, is that there is a transfer of **energy** every time an organism eats. This transfer is less than 100% efficient; not all the food energy a moth ingests gets passed on to the frog that eventually eats it. Growing, finding food, escaping from predators, and keeping warm (for warm-blooded animals) all take energy that is “burned off,” i.e. that does not get passed on. A rule of thumb people sometimes use is that just 10% of the energy at one level of an energy pyramid gets passed on to the next level. That’s why there are millions plants, thousands of mice, and just a few pumas. The amount of energy available to a top consumer is much smaller than all the light energy available to green plants.

Extensions and Resources

These are surface treatments of very complex topics. Resource abound for teaching ecology, especially as it applies to the environment.

- The Private Eye is a program that uses jeweler’s loupes as a tool to develop close observation and analogizing skills. It is very interdisciplinary and applies them to science, art, and writing.
- Flying Turtle is a very kid-friendly ecology site, but the writing is very lively, and the drawings are clever enough to keep teens and adults interested. The home page is <http://www.ftexploring.com/index.html> An in-depth discussion of energy and ecosystems begins at <http://www.ftexploring.com/photosyn/photosynth.html>.

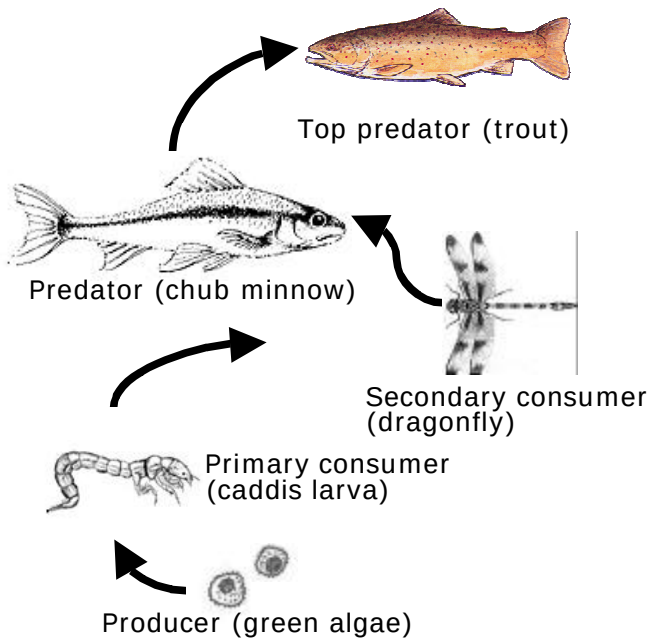
Discussion Questions

- Do you think it is important to preserve threatened and endangered species? Why? What is the value of biodiversity?
- What is a **keystone predator**? Why might removing a top predator like trout from an ecosystem be more damaging than removing a species of primary consumer?

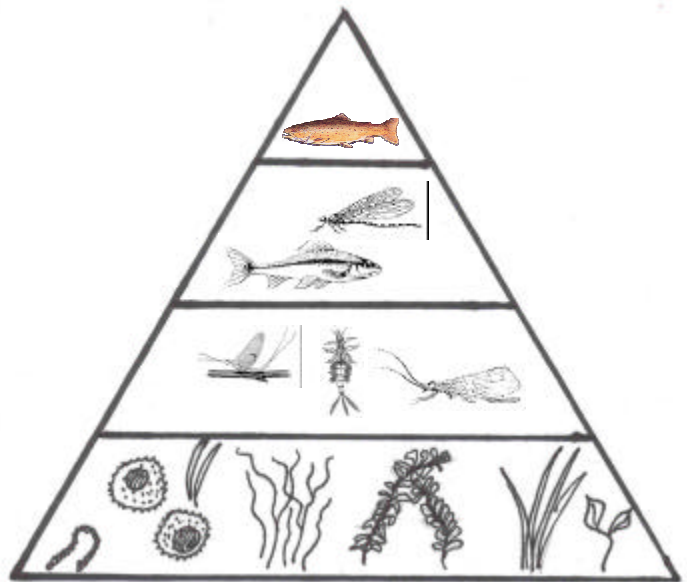
Three Ways of Describing an Ecosystem

7

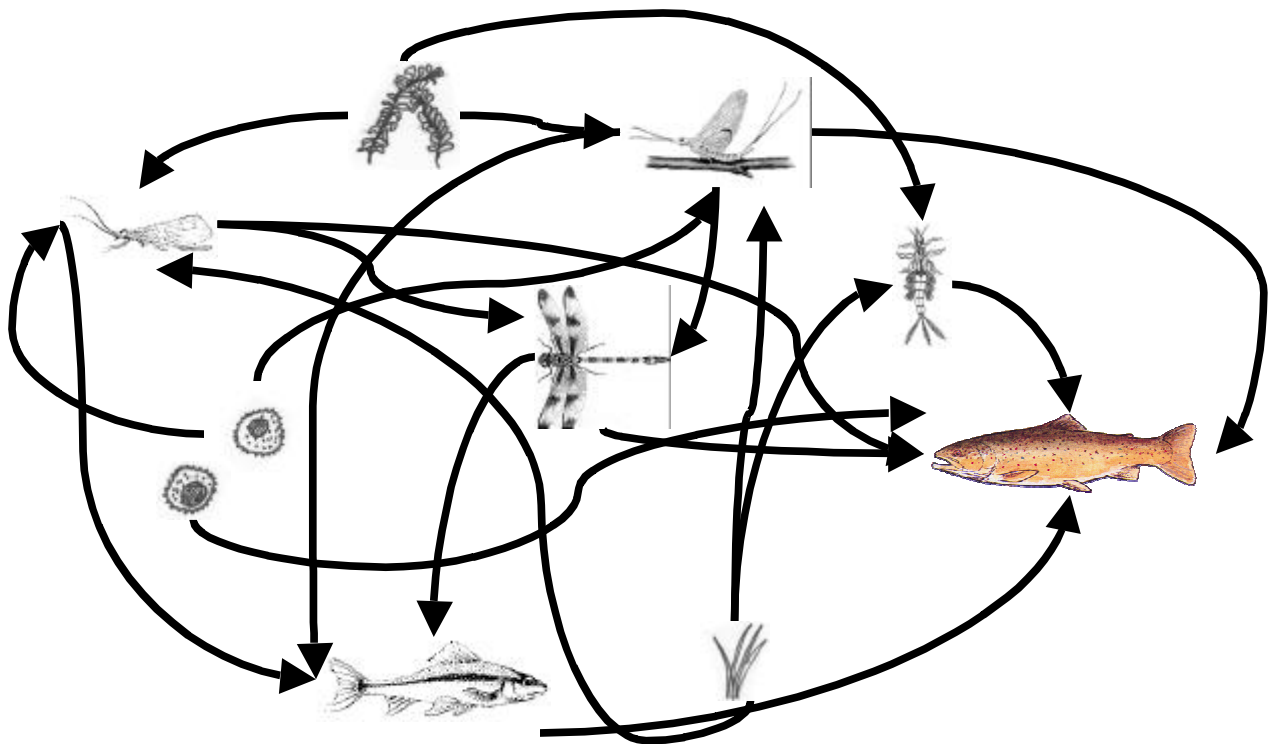
Food Chain



Energy Pyramid



Food Web



Trout, caddis larva, mayflies, and dragonfly by Andy Cooper

Caddis adult, chubb minnow, and damselfly by Bob White, *Essential Fly Fishing* by Tom Meade,
<http://www.tutv.org>

Activity #1: Stream Sense

Introduction

This field trip activity helps students discover how their senses provide them with details about stream ecosystems. By making careful observations, students experience how their other senses (besides sight) provide them with additional information about the environment.

Safety rules **MUST** be followed when students explore a stream.

Time: 1hr. on-stream, plus discussion

Ages: all ages

Materials

- Pencil and stiff-backed notepad or journal for each student
- Optional materials:
 - Camera
 - Tape recorder
 - Binoculars
 - Magnifying lenses
 - Sample foods (edible plants and seeds) that could be found near a stream
 - Spray bottle

Prep Work: instructor should visit field trip site prior to activity. (See **Stream Walk Safety Rules** below.)

Stream Walk Safety Rules

Teacher Responsibilities

1. Visit the stream first to determine if it is safe for students to visit. Check stream depth, velocity, and temperature. Also look for walking conditions, potentially dangerous wildlife, poisonous plants, etc.
2. Bring along a first-aid kit.
3. Define stream walk boundaries; make sure students understand that staying within the boundaries protects wildlife and students.
4. Locate a place where students can wash hands after the visit.

Rules for Students

1. Students should stay with their assigned buddies.
2. Students should wear old athletic shoes or boots because they will likely get wet and muddy.
3. Students should not enter the stream without supervision.
4. Students should not touch wildlife or taste anything (plants or water) unless permitted by teacher.

Procedure

1. Tell students they will be visiting a stream and will be recording how they use their senses to observe the stream. Discuss the *Stream Walk Safety Rules*.
2. Ask students to record their observations. Students should write things down or draw things as they perceive them.
3. Throughout the trip, remind students about using multiple senses. Ask students to find a quiet spot near the stream and have them sit very still to look, smell, listen, and feel. Older students may want to sit for 15 minutes or more, while for younger children, 2 or 3 minutes is probably enough. Students may want to take photographs or tape record sounds in addition to writing and drawing.
4. Other sensory activities that students could do at the stream include the following:
 - Have them block one or more of their senses (e.g., close their eyes, cover their ears, plug their noses). How does this affect their other senses? Did students hear better when they could not see?
 - Have students guide a blindfolded partner to his or her quiet site. Have the blindfolded partner recall sounds, smells, and feelings he or she experienced along the way.
 - Supply students with ways to improve the ability of their senses (e.g., use binoculars, spray water on their noses [moisture traps scent particles], cup their hands behind their ears).

Discussion

Questions to ask during or after the stream visit.

Sight: What plants and animals do they see? Does the appearance of the stream vary with location? Is the stream fast or slow moving? How can they determine its speed?

Sound: What sounds does the stream make? Can they hear animals? What does the wind sound like?

Smell: How do smells near the stream compare to those on a road or in a home? Does the water smell the same as tap water?

Touch: What does the stream water feel like? How does soil near the stream feel compared to soil in the woods or schoolyard? Are the rocks in the stream smooth or rough?

Extensions

This activity might be used as an introduction to a stream or watershed that students would later work with in greater depth. Later visits might involve **Activity #8, Stream Safari (p. 35)** and **Activity #9, Water Quality Bioassessment (p. 39)** or using the ***Water Quality Conditions, Land Use Conditions, and Physical Conditions*** worksheets (pp. 87-92) to investigate the water quality.

Adapted from Project WET *Curriculum & Activity Guide*, “Stream Sense,” pp. 191-3

Activity #2: Connect the Critters

Introduction

This is a fun, quick activity for younger kids. It will also provide insights for later discussions of ideas like biomagnification.

Time: approx. 30 min.

Ages: up to 6th grade

Materials

- A copy of the **Connect the Critters** handout (p. 13) per student
- Crayons, markers, or colored pencils

Prep Work: gather materials

Procedure

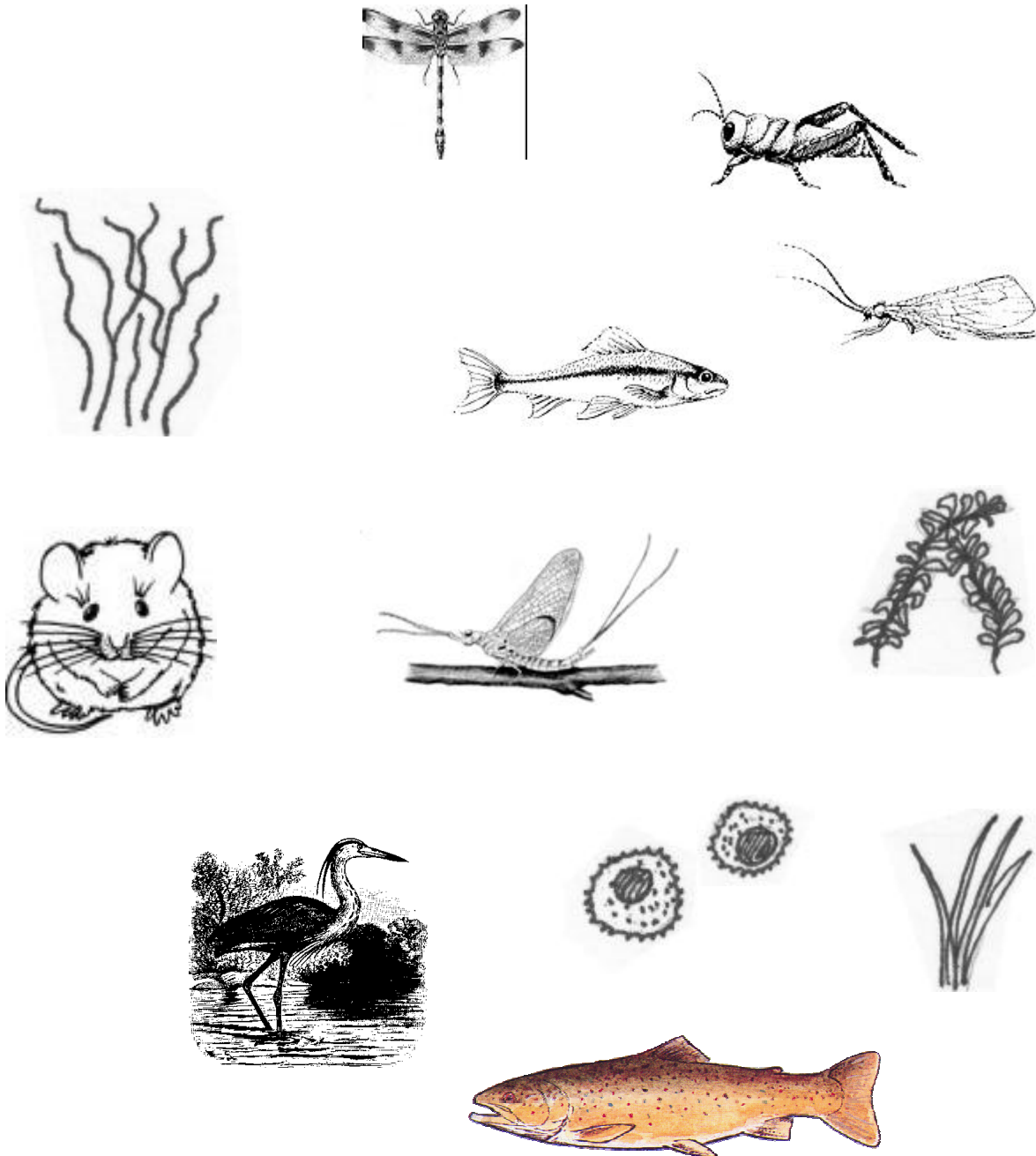
1. Ask for student input: as a class, point out each producer. Have students circle each producer with a green crayon.
2. As a class, find the primary consumers. Circle them with another color. Do the same for secondary and tertiary predators.
3. Now have students draw arrows, with arrows pointing from “eat-en” to “eat-er,” i.e. from plant to herbivore, or consumer to predator.
4. When students are finished, examine drawings as a class. Ask students to think about the assignment as you work through the discussion questions.

Discussion

- Were any animals circled with more than one color? Discuss the terms herbivore (plant-eater), carnivore (meat-eater), and omnivore (plant and meat-eater).
- Is the flow of energy in an ecosystem at all similar to the flow of water in the water cycle? How is it different?
- What happens when one organism is removed? How many of the arrows would disappear? How many animals fed on it?
- What would happen if a poison was introduced to the web at the level of the producers or some of the primary consumers? Introduce the idea of **biomagnification**.

Connect the Critters

Draw arrows showing the flow of food, or energy, in this riparian/aquatic community. How many links can you draw? What happens if you remove one member of the ecosystem? How many other organisms lose part of their food supply? Is this ecosystem representative of a real one?



Andy Cooper: Mayfly, dragonfly, brown trout, caddis

Bob White (http://www.tutv.org/general/general_html/trout_food.html): caddisfly, grasshopper, chubb minnow

Mouse from <http://mammary.nih.gov/services/news.html>

Chapter 3, Hydrology

New Ideas

- The Water Cycle
 - Handout and Overhead: The Water Cycle, p. 19
- Watersheds

Activities

- Activity #3: Water Cycle Fill-In, p. 18
 - Handout: The Water Cycle, p. 19
- Activity #4: Create a Watershed, p. 21
- Activity #5: Sum of the Parts, p. 22
- Activity #6: Just Passing Through, p. 24

Introduction

Hydrology is “the study of the earth’s waters, their distribution, and the (water cycle)” (Webster’s New World Dictionary). An understanding of basic hydrology gives insights into trout habitat, and it gives us some ability to predict how human disturbances will affect trout populations.

New Ideas: The Water Cycle and Watersheds

The quantity of water on earth is fixed and finite. Water is never created or destroyed, just moved around from place to place, or organism to organism. The **water cycle** is the name we give to the process by which water is used and recycled by earth’s biological and geological systems. Look at a picture of the earth from space: seventy-one percent of its surface is covered with water! Only a tiny percentage that supply is fresh water that is available for human consumption. There are:

469,075,897,682,999,895,388	gallons of water on earth
14,072,276,930,489,996,862	gal. <i>fresh</i> water (about 3% of the total)
2,814,455,386,097,999,372	gal. <i>liquid</i> water (i.e. not in the ice caps)
14,072,276,930,489,997	gal. <i>accessible</i> water (not too deep underground to get or too polluted to drink)

The fraction of water that humans can use is only 3/100,000 of the water on earth—the same proportion as a medicine dropper’s drop in a quart of liquid.

On an average day, an average person uses about 80 gallons of water. There are about 6 billion people on earth, so all together we use 480 billion gallons per day. If water were destroyed every time an organism used it, humans alone would exhaust the earth’s accessible fresh water in less than 81 years, one person’s lifetime. Fortunately for life on earth, used water is cycled through the **hydrosphere** over and over again. We call this the **hydrological cycle**, which means the same thing as the water cycle.

The Water Cycle illustration (p. 19) outlines the elements of the water cycle. Use the handout as a visual aid for explaining the cycle, or as an activity for students to fill in later, on their own.

Start at an arbitrary point in the cycle and trace the different paths a drop of water can take as it travels around the earth. Clouds are made of **water vapor**. **Vapor** means

that the water is in its gaseous form, like steam. The vapor **condenses** (turns from gas into liquid) around particles of ice or dust and collects into a **cloud**.

When the clouds cool off, the water **condenses** into larger droplets and falls to earth as **precipitation**. **Precipitation** is a term that includes rain, snow, sleet, and hail. Some precipitation **evaporates**, or changes from liquid back into gas, before it even it's the ground. This water returns to the clouds.

Much precipitation also falls onto the earth's surface. Since 71% of Earth's surface is covered with water (mostly ocean), some precipitation falls right into bodies of water (Bartoli 2001). We are most familiar with the precipitation that falls on land. This precipitation can meet a number of fates.

Water can evaporate back into the atmosphere before it collects or soaks into the ground.

It can flow in the direction gravity pulls it, off the land into a body of water. This is called runoff. A **watershed** is an area that collects runoff and routes it to a body of water; the EPA calls watersheds "those land areas that catch rain or snow and drain to specific marshes, streams, rivers, lakes, or to ground water." Every small watershed is part of a bigger one. A glacial basin high in the Sierras is a watershed; snowmelt and spring creeks drain into a cold alpine lake. That watershed is part of a larger one, though, and that larger one flows into a larger one in the Central Valley, which ultimately flows out the San Francisco Bay. Think of a branching pattern, like a tree. The smallest twigs are little rivulets that join into seasonal streams, which join to form streams that flow year-round, which drain into a big river, which eventually drains into the ocean. The volume of water gets bigger with each step, like moving from the branches to the trunk of a tree. **Activity #4, Create a Watershed** (p. 21), demonstrates this basic concept.

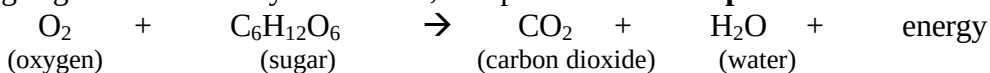
As illustrated by the **Activity #5, Sum of the Parts** (p. 22), water isn't the only thing that flows through a watershed. Coconuts and water lily seeds are built to float. The plants depend on water to disperse the seeds and find new habitat for their offspring to live in. It is a powerful solvent, picking up minerals and chemicals from the substrates over which it flows. That can bring nutrients to the water, which helps aquatic plants and animals grow. It also makes water an important element of geological processes like erosion and cave formation. It can also be problematic. Water's special solvent properties also make it easy to pollute; it will pick up any chemicals or bacteria to which it is exposed.

When water evaporates, it leaves these pollutants, or any dissolved chemicals, behind, so that rain consists of clean water (unless it picks up new pollutants from the air on its way to earth).

Some water is absorbed by plants. Plants use their roots to take up water from the ground. They use water and sunlight to make their food, sugar, in a process called **photosynthesis**. By middle school, most students have seen the following chemical equation for photosynthesis:



Plants use photosynthesis to create sugars, but it also gives off a very useful byproduct: oxygen. Animals take advantage of this by eating plants for energy and breathing the oxygen they place in the atmosphere. We also benefit indirectly from their effects on water. Absorption by plants is one of the steps in the water cycle where water can be purified. After taking up water to carry out photosynthesis, plants “burn” energy-giving sugars the same way animals do, in a process called **respiration**.



The clean water that plants give off when they respire is in gaseous form; we call it **transpiration** when this water passes through plants’ pores into the atmosphere.

Plants also help clean water by controlling erosion. Having live plant roots and bits of dead organic matter in the soil creates obstacles that water has to flow around as it moves downhill. This keeps water from washing away the soil, which both saves the soil for plants and keeps sediment out of oceans, streams, and lakes. This role is detailed in the **Activity #6, Just Passing Through** (p. 24).

Water that falls on a permeable (porous) surface can percolate into the earth to become groundwater. This water is filtered through soil, sand, and porous rocks to become part of an underground reservoir system called an **aquifer**, where groundwater is stored. Groundwater is invisible to humans, except where there is an outlet, a spring or well. While an aquifer acts like a big, underground stream or tank, the water in an aquifer is actually stored in the spaces between particles of gravel or sand. The water in an aquifer is naturally clean and cold, because it is filtered through the soil as it **recharges**, or seeps from the surface to the aquifer.

Aquifers are important sources of irrigation and drinking water. Currently, though, many of them are threatened by overuse. Human populations and needs are growing, but the rate at which aquifers recharge is the same as it has always been—namely, much more slowly than humans use water. Using groundwater faster than it recharges is called **water mining**. It can cause the water table to drop so that wells must be dug deeper underground, sometimes to a point that exceeds what people can engineer. It can also reduce the quality of well water. The Ogallala aquifer is America’s most famous aquifer, and a case study in water mining. The aquifer is huge; It stretches from Wyoming to Texas and includes areas in eight different states. The total volume of recoverable water in the Ogallala aquifer is $4 \times 10^{12} \text{ m}^3$, about the same as Lake Huron. From the 1940s to the 1970s, irrigation development in the region exploded, and the water table dropped as fast as 1 foot per year! Because of more efficient irrigation techniques, the water table has stabilized somewhat, but in the 1990s another series of droughts caused rapid drops in the water table. (Thorbjarnarson, 2002) An overdraw problem found in coastal areas is called **saltwater incursion**. Water can flow between an aquifer and a body of surface water: many streams are fed by springs, and streams sometimes recharge aquifers. Similarly, the sand near a seashore has a saline water table.

Human settlements created slightly inland, where freshwater springs are available, sometimes draw out too much of their water. When this happens, salt water can seep into the fresh aquifer, and render it useless.

References

Barilotti, 1997

The Groundwater Foundation, 2001

Thorbjarnarson, 2002

Activity #3: Water Cycle Fill-In**Introduction**

This activity helps students think about water's movement within the water cycle. It also illustrates how every drop of water is recycled over and over again.

Time: 20 minutes

Ages: elementary and middle school

Prep work: gather materials

Materials, per student:

- copy of handout (**The Water Cycle, p. 19**)
- pen or pencil

Procedure

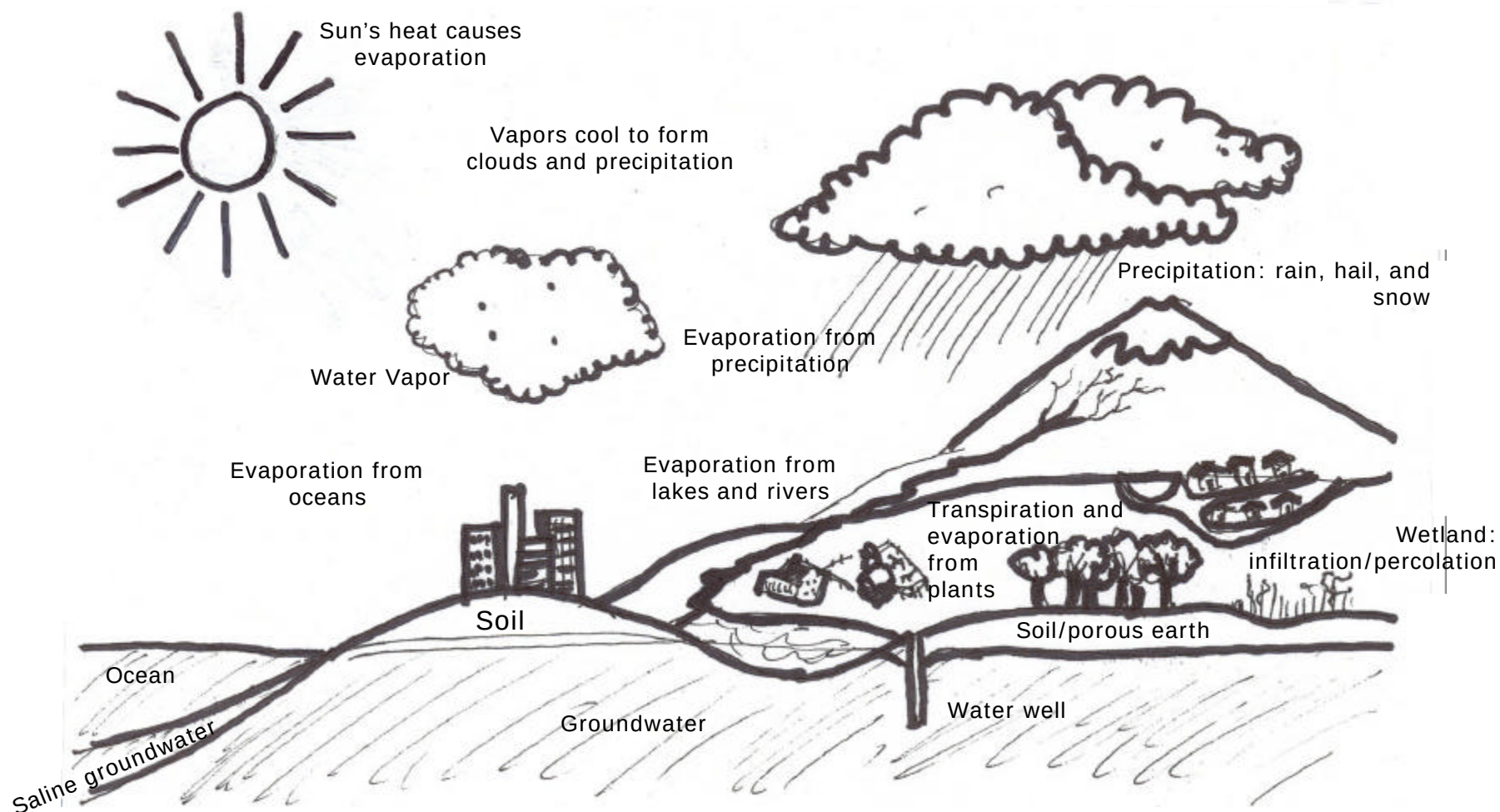
Have students fill in arrows to represent the movement of water through the water cycle. Draw as many links as one realistically can.

Discussion

Have students get together and discuss the different ways in which they got from one point to another, e.g. what are some different paths one could take from a lake to the ocean?

The Water Cycle

Fill in arrows to represent the movement of water. For example, one will connect the water vapor to the cloud it becomes, another can represent runoff flowing from the mountaintop to the stream.



After Groundwater: A Primer for Pennsylvanians

PA Water Resources Education Network (WREN) and League of Women Voters of Pennsylvania Citizen Education Fund

Activity #4: Create a Watershed

Introduction

This activity makes the concept of a watershed more concrete. It helps students understand what a watershed looks and functions like, and how all activities within the watershed affect its health.

Time: 20 minutes, plus discussion

Ages: upper elementary and older

Prep Work: none after gathering materials

Materials, per group of 3-5 students:

- Water-based markers
- Shallow baking pan or cookie sheet with sides
- Spray bottle filled with water
- A large sheet of stiff paper

Procedure

1. Have students crumple the paper into a ball and then unfold it, leaving ridges, depressions, and elevated areas.
2. Color along the ridges and “hills” of the watershed with green, brown, and gray markers to represent different land uses and pollutants, e.g. green could represent fertilizer and gray could represent industrial waste.
3. Use a blue marker to trace the streams or paths over which you think water will flow.
4. Lay the sheet in the pan and arrange it so that it resembles landforms.
5. Begin **slowly** misting the watershed with the spray bottle. Encourage students to discuss what’s happening as colors flow downstream and mix, and notice how far they travel.

Discussion

Ask students what happened to the colors as it “rained” on the watershed. How does this reflect what happens in a real watershed? What happens if communities don’t protect watersheds with responsible practices and policies?

Adapted from Earth Force GREEN *Protecting our Watersheds Activity Book*, Activity #1, “Create a Watershed.” See <http://www.green.org/> to order.

Activity #5: The Sum of the Parts

Introduction

This activity demonstrates how each watershed user affects every downstream user of the resource. This activity would also work well with **Ch. 7, Human Impacts**. It emphasizes that different landowners have different agendas, and that regulations will affect industry, agriculture, homeowners, and recreational users in different ways. Review the terms **point source** and **non-point source pollution** (p. 64) before you begin the activity. A **point source** is an identifiable, localized source of pollution, like a sewage ditch or factory effluent. A **non-point source** is one without an identifiable source, like agricultural (fertilizer) or roadway (motor oil) runoff.

Time: about an hour

Ages: upper elementary to middle school

Materials

- Long sheet of poster paper or newsprint
- Drawing pens and pencils
- Office supplies (e.g., pencils, paper clips, books)

Prep Work

Using a blue marker, number and divide the paper as shown, so that there is one section for each participant. Draw on the river and mark off equal-sized sections. Each section should include some water and some riverbank (as in Fig. 1). Cut the sections and laminate them, if you like.

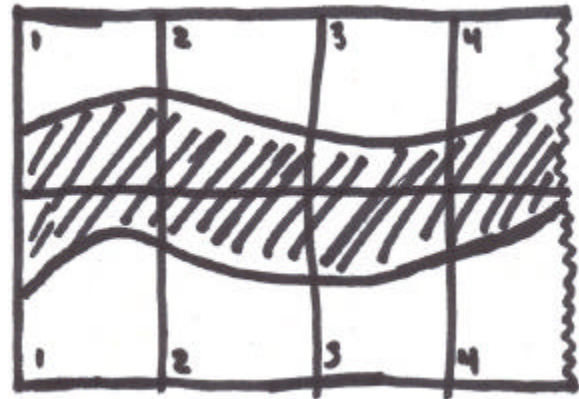


Fig. 1

Procedure

1. Inform students that each of them has just inherited a piece of riverfront property and a million dollars. Have them list ways they could use the land and the money.
2. Pass out “pieces” of property and drawing pens and pencils. Explain that the blue is water and the blank space is land they own. They have one million dollars to develop their land as they wish. They can farm or ranch; build resorts, homes, factories, or parks; plant forests, log, mine—whatever they like.
3. When students have completed their drawings, ask them to look in the upper left-hand corner of their property for a number. Explain that each piece is actually a part of a puzzle. Starting with number one, have students assemble their pieces. They will construct the stream pathway and adjacent land area in proper order (Fig. 1).
4. Have students describe how they developed their land and how they used water. They should identify any of their actions that polluted or added materials to the

- waterway. Have students represent each of their contributions to the river with an item from their desks (e.g., book, piece of paper, pen, pencil).
5. Tell students to take their item(s) and line up in the same order as their pieces of river front property. They are going to pass their pollution pieces downstream. Have them announce what kind of pollutant they are holding before they pass it on. The ones will pass their item(s) to the twos, the twos will pass everything to the threes, and so on, until the last students are holding all the items.

Discussion

After all the items have reached the final students, discuss the activity. How did those students toward the middle or end of the river feel? What about their property use plans? Could a student downstream be affected by the actions of a student upstream? Could upstream users alter the quality of those downstream?

Tell students to reclaim their items. Explain that the items easily identifiable as their own simulate point source pollution. Other items (e.g., pencils, paper clips, notebook paper) may be more difficult to claim, because these kinds of pollutants originated from multiple sources. Tell students these represent nonpoint source pollution.

Discuss ways that each student might reduce the amount of pollution he or she contributed.

Adapted from Project WET *Curriculum & Activity Guide*, “Sum of the Parts,” p. 267-270

Activity #6: Just Passing Through

Introduction

As water flows, it filters through the spaces between grains of dirt and around plant roots and organic matter in the soil. Vegetation slows this flow, and also keeps water from washing away the soil. Without plants, soil is to be carried away in the process called **erosion**. Erosion is a natural and important geological process, but if too much vegetation is removed from riparian areas, water carrying soil, organic matter, and pollutants can cause excess sedimentation in streams and harm aquatic life.

This activity illustrates the way that vegetation affects water's movement through a site. It helps students understand the way that landscape and human activity affect erosion, and hence water quality.

Time: approx. 50 min.

Ages: upper elementary to middle school

Materials

- Playing field
- Yarn or rope (the length of the playing field)
- Biodegradable items (such as peanuts) (optional, for Part III only)

Prep Work: approx. 20 min.

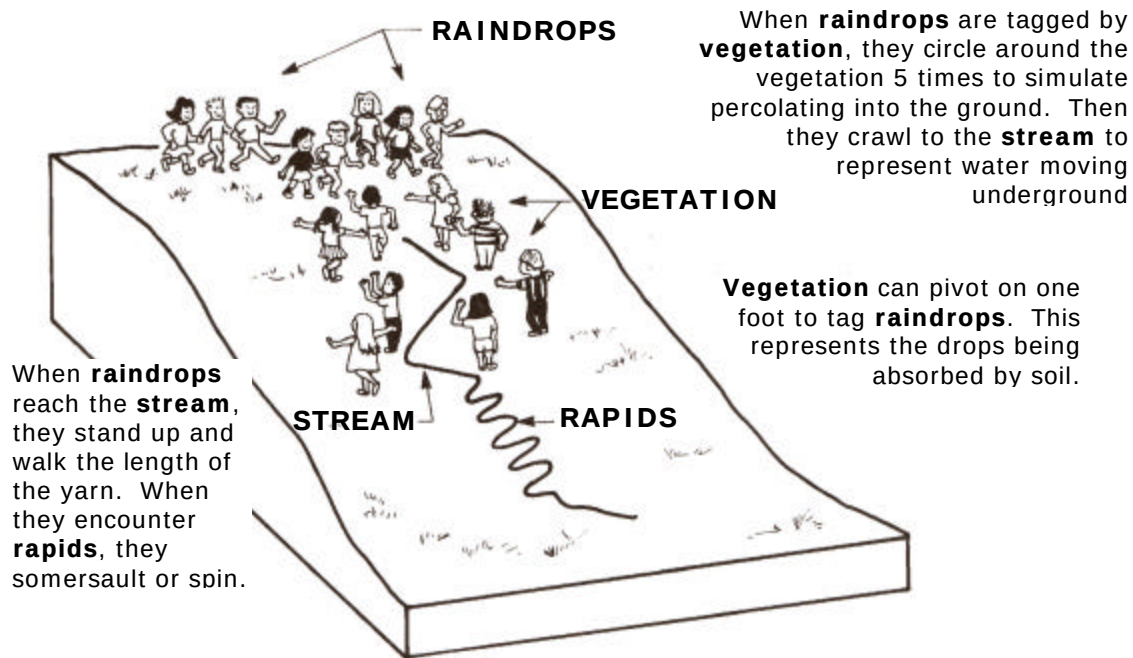
- Set up field as in *Slope with Plant Cover* diagram (next page)
- Before Part III, scatter “sediment” of biodegradable items like peanuts and leaves on field

Procedure

Part I

1. Arrange the playing field according to the diagram *Slope with Plant Cover* (next page). Lay yarn or rope as shown to indicate the stream and rapids. Have half of the class assemble at one end of the playing field. These students represent “raindrops.” The remaining students represent “vegetation” and should position themselves somewhere between the raindrops and the stream.
2. Announce a rainstorm. Raindrops move into the site and quickly walk the most direct route to the stream to represent water falling on and flowing over land.
3. Vegetation on the slope slows the flow of water. Students representing vegetation try to tag the raindrops. Vegetation must keep one foot in place, but can pivot and stretch their arms (representing roots trapping water).

Slope with Plant Cover



4. If raindrop is tagged, he/she simulates filtering into the ground by circling five times around the vegetation. To represent water moving underground toward the stream and passing through spaces among soil particles, raindrops should crawl slowly towards the yarn. Raindrops cannot be tagged a second time.
5. Once raindrops reach the stream, they stand up and walk the length of the yarn. If they encounter rapids, they can spin about or do forward rolls to represent water spilling over rocks. At the end of the stream, they should wait for the rest of the raindrops.
6. Record the time it takes all the raindrops to pass through the site. If they want, students can exchange roles and repeat the simulation.
7. **Discuss** the results of the activity. Ask students to describe water's movement. Help students to understand how vegetation slows the rate of flow, which allows time for water to percolate into the soil.

Part II

1. Ask students how the results of the activity will differ when vegetation is removed. Have students perform a second version of the activity.
 - Half the students represent small rocks by sitting or lying down and curling themselves into tight balls. The other half represent raindrops.
 - When raindrops move near a rock, they can walk around or jump over it, continuing to flow down the slope.
2. Compare the time required for raindrops to flow through sites with and without plant cover. **Discuss** the implications of water racing down a barren slope.

Part III

1. Set up the playing field as in *Part I*. As raindrops flow through the site, they pick up sediment (pebbles, twigs, dead leaves, or biodegradable items, such as peanuts, scattered by the instructor). If tagged, raindrops percolate or filter into the ground. They drop all the tokens they have collected (symbolizing soil filtering raindrops and removing sediment). Once raindrops are tagged, they circle five times around vegetation and crawl to the stream. (They do not pick up any more sediment.) Remind students about gravity; raindrops must keep moving as they bend down to collect materials.
2. After raindrops make it through the site, have them count the number of items that they are still holding.
3. Arrange the field as in *Part II* and have raindrops flow through the site picking up sediment. At the conclusion, students should find that a larger amount of sediment has been collected by the raindrops than in the previous simulation.
4. **Discuss** problems associated with erosion and unchecked transport of sediment. Introduce Best Management Practices that can be used to control erosion. Remind students that erosion is a natural process (necessary for adding minerals to streams and creating landscapes). However, because a large amount of sediment is being removed within a short period of time, this simulation (*Part III*, step 4) represents erosion that could be harmful.

Extensions

How does a lake affect the movement of water through a site? Make the playing field similar to that in **Part I**, but add a lake (a large circle of yarn or rope at the end of the stream). Have raindrops move through the playing field. When a student enters the lake, he or she cannot leave until four more raindrops enter the area. (They can stand in line and make a “wave,” moving their arms up and down in a waving motion.) How did the lake affect the rate of water movement? Students may respond that after moving quickly through the stream, they were slowed by the lake.

To introduce how lakes can be affected by surrounding areas with and without plant cover, try the following. Show students a clear glass of water and pour in some sand or soil. Note how materials begin to settle out. Explain that this happens when water is standing in a lake as well. Arrange the playing field as in **Part II** and have raindrops pick up sediment as they move toward the stream. When a student enters the lake, he or she waits for the fifth student to enter. Raindrops discard their sediment before leaving the lake. Discuss how a lake could be affected by an accumulation of sediment. (If stream sediment continues to be deposited in the lake, over time the lake could become shallow or even fill. High levels of sediment can adversely affect aquatic plants and animals.) What could be done to decrease the quantity of sediment flowing into the lake? Students may want to repeat this simulation, but with a playing field similar to that in **Part I** (site with plant cover) and compare sediment levels.

Have students inventory their school grounds or community, looking for land areas that compare to those demonstrated in the activity. During a rainfall, students can observe the area’s runoff and the amount of sediment carried by the water. Students can plant trees or landscape a garden to improve an area that has erosion problems.

Adapted from Project WET *Curriculum & Activity Guide*, “Just Passing Through,” p. 166-169

Chapter 4, Stream Life

Use with fishing skills **FLY TYING** or **READING THE WATER**.

New Ideas

- **Trout Food**
- **Metamorphosis**
- **Adaptation**

Activities

Activity #7: Insect Life Stages Fill-In, p. 33

- o Handout: Insect Life Stages, p. 33

Activity #8: Stream Safari, p. 35

- o Handout: Make Your Own Kick Net, p. 37

Activity #9: Water Quality Bioassessment, p. 39

- o Handout: Bioassessment Worksheet, p. 41

Review and Related Ideas

- o Habitat and Niche (Ch. 2, p. 3-4)
- o Food Webs and Energy Pyramids (Ch. 2, p. 4-5)
- o Pollution (Ch. 7, p. 63-67)

Introduction

Most anglers have some idea of what trout feed on, and have, at the very least, used caddis, mayfly, or stonefly imitations. Still, many anglers who have fished elk hair imitations might not recognize a live caddisfly. Knowledge of small aquatic animals, and insects in particular, is the core of fly fishing. They are also widely recognized as a sort of biological litmus paper: biologists, hydrologists, and environmental scientists all inventory aquatic invertebrates (insects, molluscs, worms, and crustaceans) to measure stream health. Techniques these scientists use are easy for students to imitate, can be used with little or no specialized equipment, and are a lot of fun. The following is a guide to the invertebrates that are most important to trout, and most commonly used to assess water quality, with suggestions for your own “bug safari.” It is a great chance to teach fishing skills and biology in a single fun lesson that will make kids better, more conscientious fishermen. This is fun because it feels like discovery. An act as simple as turning over a rock to find something new can deepen one’s appreciation of a stream forever.

While the heart of this lesson is the on-stream exploring, a little preparation beforehand will make the scientific exploration much richer. If you’re running a short program, the most important thing to do is to give students a taste of the excitement and wonder of discovery. If your program is stretched out over a much longer period of time, several classes before the actual stream trip can be devoted to the basics of bugs.

Teaching Tips

Much of this can come out as discovery learning on the stream, after insects have been collected. Students will probably come up with a lot of questions as they observe the organisms they have collected, but it is helpful to have a number of questions in mind to ask them.

The **Trout Food** section below will not be terribly interesting to students unless you can collect pictures or specimens of the different groups you talk about. Find out if your local university or extension station has an insect collection. The head curator, a graduate student, or a volunteer will likely be willing to give your class a tour, or bring some specimens in and give a short lecture.

Another way to make the biology in this section more accessible is to relate it directly to fishing gear and techniques. Use artificial flies to illustrate the different body forms of nymphs and adults, aquatics and terrestrials.

Trout Food

To catch fish, we present lures that look like the things wild trout eat. For most trout, even very large ones, most of the diet is made up of small **invertebrates**, or animals without backbones. Some of the invertebrates that are important parts of the trout diet are:

- **Arthropods**, which have segmented bodies and hard exoskeletons. The most common arthropods are **insects**, the six-legged arthropods. Most of the flies we fish with imitate insects. Some are **aquatic**, or have aquatic stages, like mayflies. Others are **terrestrial**, or land insects, like beetles and grasshoppers. Trout eat these when they accidentally fall into the water.
- **Crustaceans**, like crayfish and scuds (brine shrimp), are another class of arthropods that trout eat.
- **Molluscs** have soft bodies, and some have hard shells. Clams, mussels, and slugs are common molluscs, but did you know that octopi and squid are molluscs, too?
- **Nematodes** are the **roundworms**. Trout eat some of these. Many flatworms, like planarians, are aquatic.
- **Annelids** are very advanced worms with segmented bodies. Leeches and the common earthworms that people use for bait are annelids.

Some trout, especially lake trout, will eat microscopic **zooplankton**, but trout will also eat **vertebrates** (animals with backbones), like frogs or other fish. Some fish are cannibalistic, and will eat smaller members of their own species! Predators that eat many different kinds of food, as trout do, are called **generalists**. The opposite kind of predator is a **specialist**, which “specializes” in catching one kind of prey.

Some trout populations have reputations for being very selective about what they feed on. Anglers sometimes refer to the need to “match the hatch,” or use flies that imitate the native insects. In fact, trout aren’t “crafty” so much as they are creatures of habit. Trout are selective in order to maximize their efficiency when feeding. If they can recognize the common foods or hatches on their home waters, they don’t need to waste energy investigating strange new foods. Lunker trout on the San Juan River drive anglers crazy because they often won’t respond to anything but midges. From the trout

perspective, why chase after unfamiliar new mayfly imitations when they can get fat eating midges?

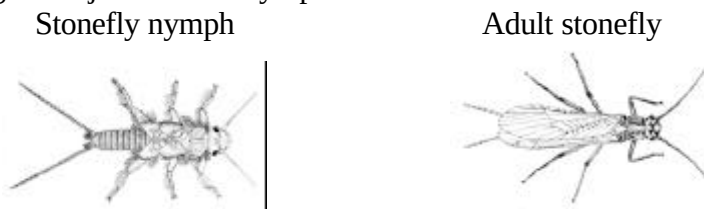
Learning about these aquatic invertebrates is useful to us not only as it relates to fly fishing, but because they are **indicator species**. Just as bass can tolerate warmer water and lower dissolved oxygen levels than trout, mosquito larvae can survive in warmer, less-oxygenated water than stoneflies. If habitat is bad for trout food, it will be impossible for trout to live there themselves. Trout and their favorite food items have similar levels of **pollution tolerance**, or ability to survive in habitat compromised by pollution. For this reason, collecting and counting the invertebrates in a body of water is a good way to get a picture of its quality, without using expensive equipment. In **Activity #8, Stream Safari (p. 35)** and **Activity # 9, Water Quality Bioassessment (p. 39)**, students will work very much like professional water quality monitors do.

The CCEG CD-ROM contains pictures and life history information on the invertebrate orders that are most important as trout food and indicators of water quality.

Metamorphosis

Why do juvenile insects look so different from adults? Because they go through **metamorphosis** as they get older. Metamorphosis comes from the Latin roots “meta,” which means “change,” and “morph,” which means “form,” or “shape.” Insect metamorphosis is a change in body plan as an insect grows from egg to adult. It can happen in two different ways.

Stonefly eggs hatch into nymphs, which look somewhat like miniature, wingless adults. They periodically molt, or shed their skin, and grow a little larger, and a little more adult-looking. Each of these little growth stages is called an instar. When the last nymph instar molts, the stonefly that emerges is an adult, which has fully formed wings and genitalia. One can see many shared characteristics on these pictures of a nymph and adult. Both have legs, cerci, and antennae, and if the adult’s abdomen were visible, it would have segments just like the nymph’s.



Some insects go through two stages, rather than one, on their way to becoming adults. Butterflies are probably the best-known of these insects; like all the others, they have four distinct life stages: egg, larva (caterpillar), pupa (cocoon), and adult. Caddis flies also go through this four-stage metamorphosis. It is common to find caddis larvae in their cases in a stream, or adults in vegetation near the water, but we rarely find caddis pupae (which would be inside the water). Why might it be important to pupate in an inconspicuous place? Does it look like a cocoon would be very good at escaping predation? Use **Activity #7, Insect Life Stages Fill-In (p. 33)** to talk about insect anatomy and metamorphosis.

Discussion Questions

- **A good question to start the discussion with is, *why bother with metamorphosis?* Why might it be advantageous to spend part of a life cycle in water and part on land?** If adults and juveniles of the same species live in different habitats, they won't compete with each other. Aquatic juveniles that feed on leaf litter and organic matter are taking advantage of a niche where there isn't much competition. Adults do not need to eat as much, and the ability to fly lets them disperse to find mates and mix their genes with those of other populations.
- **Why is it often easier to catch fish on nymphs than on dry flies?** Insects usually spend a much longer period in the nymph or larval stage than they do as adults. Trout naturally get to feed on nymphs more than they do on adults, so they usually search for food under water. In addition, trout feeding under water are less exposed to predation than those feeding on top.

Adaptation

The concept of **adaptation** follows naturally from a discussion of metamorphosis. Insects that have aquatic larvae or nymphs and terrestrial adults are adapted for different habitats at each life stage. Sometimes they have entirely different body parts at different stages. For example, the stonefly nymph pictured above uses gills to breathe. By the time they are adults, they lack gills and breathe through tiny tubes in their skin. Other features just look and function a bit differently in nymphs and adults. The nymph's legs are thicker, stronger, and flatter than the adult's, so that it can hold on tight to rocks in the fast riffles it inhabits. The adult has thinner legs with less pronounced claws on its feet. It moves around by flying, and big legs would hinder its movement more than they would help.

Adaptations can be behavioral, as well as physical. For example, mayfly adults emerge at dusk. One advantage of emerging at night is that their predators, fish and birds, locate their prey primarily by sight. Emerging when light is low makes it more likely that they will survive long enough to break free of the water's surface tension, mate, and lay their own eggs.

Give a simple homework assignment: have students go home and observe their own house pets and note a few different physical and behavioral adaptations. One might give a starter assignment like, "Domestic cats are often quite active at night. Which of their features seem to be adaptations for navigating and hunting in the dark?" (big pupils, whiskers, strong senses of smell and hearing)

On your class's field trip, use **Activity #8, Stream Safari (p. 35)** to draw out ideas about adaptation. Ask students to ponder how different body shapes, sizes, and appendages might be adaptive.

References

McCafferty, 1983
 Merritt & Cummins, 1996
 Pobst, 1990

Insect Life Stages

Find and fill in the corresponding body parts on the nymph and adult mayflies. Make sure to fill in these ones, plus any others you can think of:

Head

Thorax

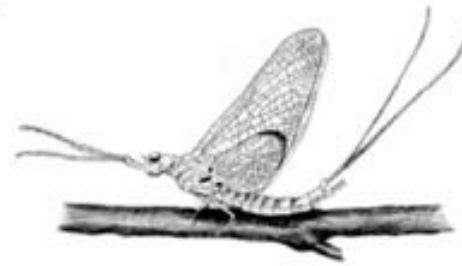
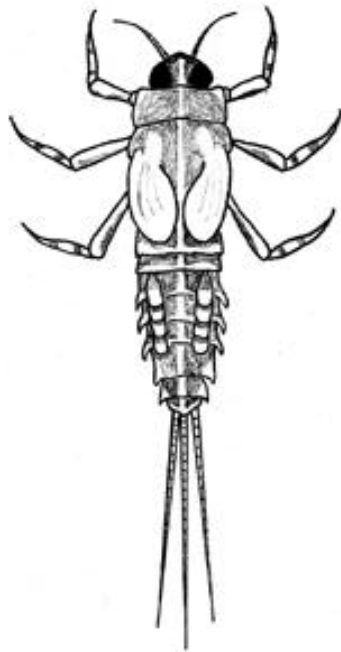
Abdomen

Cerci

Antennae

Legs

Wings or wing
pads



Question to think about:
how is the nymph adapted
for life in the water, and
how is the adult adapted for
life in the air and on land?

Activity #8: Stream Safari

Materials

Different sampling techniques are appropriate for different parts of the watershed. Essential equipment for an insect inventory includes:

- **Waders** or high boots
- **White capture buckets, trays** and **coolers** for holding the collection. White bottoms make it easy to see the animals, and some insulation will keep them alive and well longer.
- **White trays, yogurt cups, or ice cube trays** for sorting collections
- **Hand lenses, jewelers loupes, or magnifying glasses**
- **Collecting Permits:** If your class plans to collect invertebrates and keep them, make sure to get the proper permits before you do so. If you want to collect in a state or national park, begin by calling that park's office. The state Department of Environment and Conservation might be another good place to start asking for permits. If the organisms you want to collect are fairly common and you are collecting for research or education purposes, government agencies usually just ask that you collect only the organisms listed on your permit and that you submit a report of what you found when you have finished collecting.
- Not absolutely essential, but **HIGHLY** recommended equipment includes
 - **Nets:** you can use several different types of nets. Each is good for sampling a different niche in the stream. The handouts provided contain instructions for making some of the following types of nets.
 - **Dip nets** can be found at pet or aquarium stores, or from entomological supply houses like BioQuip. They are used for catching things you can see, but there's lots one will miss upon first glance...
 - A **kick seine** or **kick net** consists of mesh strung between two vertical poles. Seines can be set up and left to collect freeswimmers, like minnows, and certain types of mayflies. Instructions are on the **Make Your Own Kick Net** handout, p. 37.
 - **Beat sheets** are held underneath trees, grass, or shrubs while somebody beats on the vegetation. Insects fall out of the vegetation and are collected on the beat sheet. Move fast to pick them up! You could also just use a light-colored umbrella held upside-down.
 - **Dissecting microscope** for close observation and identification
 - **Tweezers** and **small brushes** for handling small or delicate creatures

Procedure

The first part of your stream safari should be a quiet session of careful observations that students write down. Information that everybody should collect includes:

- A physical description of the stream. How fast is the water moving, and how turbulent is it? How many riffles are there? Estimate its width and depth. Is it a straight channel, or does it meander in **S**-curves?
- What is the bottom like? Is it cobbled, sandy, or bedrock? Are there algae or weeds? Concrete or sediment?
- What kind of cover is available for animals? Are there permanent snags or rocks that slow currents and provide a place to hide from predators?
- What is the stream bank like? Is it sandy or rocky? Does it appear to be eroding? Is there a vegetated overhang to hold insects or provide cover? Are there shading trees on the bank? Is it artificial, like concrete riff raff?
- What, if any, evidence of human activity do you see? Can you see trash or fishing tackle? Can you hear a highway? Do you see erosion that might be evidence of grazing cattle? How wide a buffer of vegetation does the stream have outside the banks?
- Does the stream smell clean or stagnant? Note any “off” or sulfurous odors.

It is important to have a safety talk before kids begin wading into a stream.

Now it's time to begin collecting. If the stretch of water that you're looking at has a number of different habitats, make sure to sample from each of them. Send one group to use a kick-net under a riffle, another to turn rocks over in the shallows, and a another to beat the streamside vegetation to collect adults. Also, in general, it is preferable to start downstream and work upwards to avoid sending sediments and organisms downstream to locations that you will later want to sample. Students should work in groups of three or more, especially if they are wading into riffles or swift water. Invertebrates can be collected with any of the net-based techniques described in **“Materials,”** or by simply reaching into the water to grab what they can and turning rocks over to find nymphs, water pennies, and scuds.

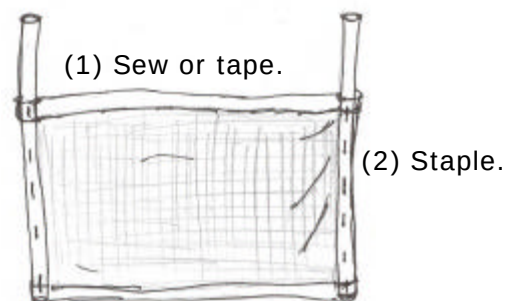
Discussion Questions

- How have different insects adapted for life in the water?
- What is the advantage of being flat if you live in fast water?
- Would you be able to guess what different animals ate without being told?
- What do their mouth parts tell you about their diets?
- How do some insects use surface tension? (Look at water boatmen.)

Make Your Own Kick Net

Materials

- 3.5' x 4' nylon mesh (1/16" mesh)
- 2 broom handles or wooden dowels
- Staple gun and staples
- Needle and thread, sewing machine, or duct tape

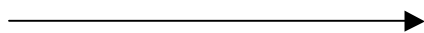


Directions

1. Hem the 4' sides of the mesh by folding over and sewing parallel to the edge. You could also just fold duct tape over the edge to prevent it from fraying
2. Lay the netting out flat and lay the dowels out along the short sides
3. Roll 6" of netting around each dowel and staple. Violá!

Using the finished product

You need at least 2 people to use the kick seine. One holds the seine perpendicular to the current. The other stands about 2' upstream from the seine and kicks the substrate (soil, gravel, or rocks). Bits of dirt and the invertebrates living inside it will float down and stick to the seine. Bring the seine up out of the water, upstream side up, to see what you netted.



Direction of current



Activity #9: Water Quality Bioassessment

Depending on the age of the students and the amount of time available, samples can be dealt with in different ways. Younger students can sort insects more or less to **order** in fresh water, right at the stream, and the insects can then be returned to their homes. **Order** is a very broad classification (i.e. the mayflies form an order called Ephemeroptera) and can be determined just by “eyeballing it” and recognizing a few distinguishing characteristics. Use the line drawings and pictures provided to sort your collection into yogurt cups or ice cube tray compartments. Tally the number of organisms you’ve collected on the **Bioassessment Worksheet (p. 41)** and multiply as directed in the bottom box. This will tell you the water quality index of your stream, and it can help predict what kind of fish will live there. Wild, reproducing trout need Class I waters.

Older students or more involved programs can take classification to the level of **family**, or even more detail. Biologists use these categories to classify every kind of organism:

Grouping	Human	Brook Trout	Baetis Mayfly (Blue-winged Olive)
Kingdom	Animal	Animal	Animal
Phylum	Chordata	Chordata	Arthropoda
Class	Mammalia	Osteichyes	Insecta
Order	Primates	Salmoniformes	Ephemeroptera
Family	Hominidae	Salmoninae	Baetidae
Genus	<i>Homo</i>	<i>Salvelinus</i>	<i>Baetis</i>
Species	<i>sapiens</i>	<i>fontinalis</i>	<i>tricaudatus</i>

These seven groupings are the standards. We always italicize genus and species, with genus capitalized. Students could find the classification, and perhaps the history of the classification, of one of their favorite fish or insects as a short research project.

Sorting insects to family usually requires the use of a dichotomous key. Using dichotomous keys is an important skill for young biologists to master. Several excellent keys are available online. Websites are listed in the **References** for this section .

Materials are the same as for the **Activity #8, Stream Safari (p. 35)** and should also include a copy of the **Bioassessment Worksheet (p. 41)** for each group of about 3 or 4 students.

Extensions

It will be easier to do family-level classifications in a classroom or lab, with dead specimens. If you intend to observe specimens in the lab, preserve them in vials (available at BioQuip, see references) filled with 70% ethanol. A dissecting scope will be necessary for looking at the specimens.

If students are really intrigued by the insects, or if you have some budding conservation biologists in your program, they can visit the EPA website to see how real-world environmental scientists work <http://www.epa.gov/owow/monitoring/rbp/>.

References: Dichotomous Keys and Biomonitoring Sites

- A wonderful key with line drawings is available online from the Izaak Walton League Save Our Streams Project at <http://www.people.virginia.edu/~sos-iwla/Stream-Study/Key/MacroKeyIntro.HTML>
- The New York Department of Environmental Conservation is creating a key with photographs. It does not yet include adult forms or the URL is <http://www.dec.state.ny.us/website/dow/stream/index.htm>
- The City of Santa Rosa (CA) has an interactive key and an extensive description of their local biomonitoring program http://ci.santa-rosa.ca.us/pworks/stormwater/biological_monitoring_programs.asp

Bioassessment Worksheet		
Investigator Names		
Stream Name	Location	Date
Habitats Sampled	Stream Width at collection site	Qualitative Observations
Water Temp	Stream Depth at collection site	
Observations of Macroinvertebrates Check off all of the types of macroinvertebrates that your group finds		
Pollution Sensitive	Somewhat Sensitive	Pollution Tolerant
___ Mayfly larvae ___ Stonefly larvae ___ Caddis larvae ___ Dobsonfly larvae (hellamgramites) ___ Gilled snails ___ Planarians ___ Water penny larvae ___ Riffle beetle (adult)	___ Clams ___ Cranefly larvae ___ Crayfish ___ Alderfly larvae ___ Fishfly larvae ___ Scuds ___ Planarians ___ Sowbugs ___ Damselfly larvae ___ Dragonfly larvae ___ Whirligig beetles ___ True bugs (water scorpions, boatmen, backswimmers)	___ Lunged snails ___ Black fly larvae ___ Midge larvae ___ Leeches ___ Worms ___ Mosquito larvae
Types found X 3 = _____ (index value)	Types found X 2 = _____ (index value)	Types found X 1 = _____ (index value)
Add the index values to get the water quality rating _____ >22 is excellent, 27-22 is good, 11-16 is fair, and <11 is poor		

Chapter 5, Trout Behavior & Biology

Use with fishing skills **READING THE WATER** and **PRESENTING THE FLY**.

New Ideas

- **The Trout Body and How it Works**
 - o **Overhead: The Trout Body, p. 49**
- **Fish Senses**
- **The Basic Trout Life Cycle**
- **The Sea-run Life Cycle**

Activities

- Activity #10: Trout Fill-In, p. 51**
- Activity #11: Color a Trout, p. 53**
- Activity #12: Which Side Are You on?, p. 55**
- Activity #13: Salmon Farming Debate, p. 57**

Introduction

Much of fly fishing is figuring out what fish eat and presenting an imitation of that food in a lifelike manner. Hence, solid understanding of trout behavior and biology will make for a much more effective angler. For conservation purposes, it is crucial to understand the life cycles of species we wish to protect. Participants should come away with an understanding of the salmonid body plan, life cycle, and senses, and how those factors influence the fish's feeding and mating behavior.

Teaching Tips

Teaching these subjects in an engaging manner may be more difficult than other lessons. It is hard to visualize a life cycle or an internal organ, so teaching short lessons with an energetic style is crucial to keeping your group's attention. During the section on the trout body, a model or taxidermy would augment the included sketch well.

We hope the handouts and activities with this section will make it more fun. Also, much of the information on how trout sense the world around them can be taught on the stream, while kids are fishing, with questions like, "Why do we often 'sneak up on' trout in a clear stream?" and, "Why is it important to keep things like sunscreen off our flies and line?"

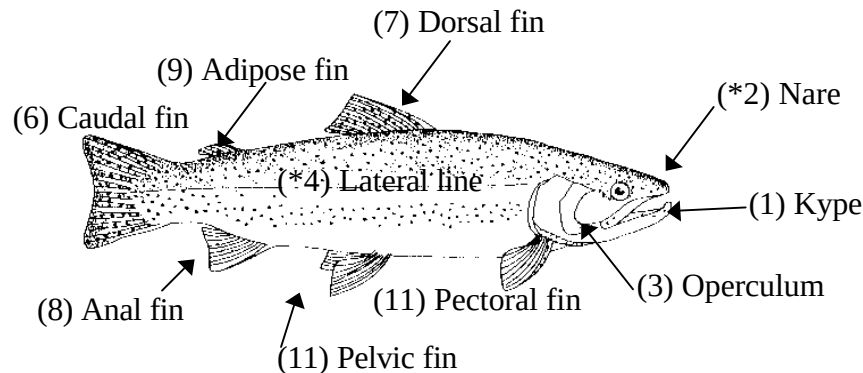
A number of activities and illustrations are available to supplement the ones in this curriculum, including:

- The Willoughby Ebus School web page, with photographs of each the salmon life stages at <http://schoolcentral.com/discussion/pacificsalmon/PS-Life-GrowthStages.htm>

The Trout Body and How It Works

Part of the reason people like to fish for trout and salmon is that they are considered beautiful. Much of their beauty has a functional root. Their torpedo-like shape, muscles, and fins are all arranged so that trout can slice through the water. That way, they can swim facing upstream with a minimum of water resistance. Conserving energy minimizes the risk of predation (by birds and mammals) that trout face every time they come to the surface to feed.

Refer to the **The Trout Body (p. 49)** as you go through the features. The features with stars (*) are sensory organs. There is more information about them in the next section.



A trout uses its **mouth** to eat; trout usually suck their food up, instead of engulfing it like bass do. Trout also use their mouths to feel things, and sometimes males use their jaws for fighting over mates. They do this around spawning time, when they have developed big (1) **kypes**, the hooked portion of the lower jaw. Trout investigate potential meals by smelling with their (*2) **nares**, much like our nostrils, or by looking at them with their ***eyes**. A trout's pupil is slightly triangular, rather than a perfect circle. This helps give it a larger field of vision. All trout breathe through their **gills**. They open their mouths wide to draw water through. Gills work much as our lungs do; they have lots of surface area for exchanging the oxygen they need for the carbon dioxide their body cells produce as waste. Lake-dwelling trout also use **gill rakers** to feed on microscopic creatures called zooplankton. Rather than gulping them up in their mouths, their gills pick the zooplankton up when the water rushes through them. The gill rakers pick the food up off the gills so the trout can swallow them. Gills are very delicate (never touch them if you are going to release the fish), so they are covered by a hard plate called the (3) **operculum**. Since trout have gills instead of lungs, their lungs have been modified into a **swim bladder** (not shown), a long, skinny, air-filled sac. The swim bladder allows a fish to float at a desirable level without constant effort. The (*4) **lateral line** is a special sense organ that runs all the way from the operculum to the tail. In addition to excretion through the gills, a trout uses its (5) **vent** to excrete extra water or salts (if it lives in fresh or salt water, respectively). The vent is also the outlet for eggs or milt during spawning.

Trout have six different kinds of fins. Four are single fins, two are paired. The biggest fin is the tail, or (6) **caudal fin**. It provides a “push” to start moving and acts like a rudder for steering. The caudal fin has many **fin rays**, the bony spikes that give fins shape. The other three unpaired fins are the (7) **dorsal fin**, the (8) **anal fin**, and the (9) **adipose fin**. “Adipose” just means that this is a fatty fin without rays. All unpaired fins are used for swimming power and stabilization. The two sets of paired fins are the (10)

pectoral fins and the (11) **pelvic (or ventral) fins**. Both sets are used like brakes, and the pelvic fins help with up-and-down movement. Students can get used to these terms with **Activity #10, Trout Fill-In (p. 51)**. **Activity #11, Color a Trout (p. 53)** gives kids a chance to be creative. They can draw the markings of their favorite trout, or they can make up a fanciful new one.

Trout Senses

A question to keep in mind throughout this topic is, “How is water a different medium from air? How do things look, sound, taste, smell, and feel differently under water?”

Humans are very visual creatures. Sight is generally is our primary way of recognizing food, shelter, and each other. Fish live under water. Water, especially if moving or dirty, scatters light, which makes it harder to see. Still, salmonids do most of their foraging by sight; the appearance of a lure is the most important attractant (or repellant). The position of a trout eyes allow them to see very clearly within a circular area called the **Snell Circle** that is directly above its head. Outside that circle, they can’t see much, but they can see the area from which most predators attack. Trout also use visual cues to communicate with each other, mostly when mating. Male sockeye salmon, for example, turn bright red when they’re ready to spawn.

Trout vision has some major limitations. If the water is murky, or if it’s dark, or if trout need to detect something outside their limited field of vision, they compensate with other senses. If an aquatic habitat is a disadvantage for vision, it is an advantage for smell. A sense of smell is the ability to detect tiny particles of different chemicals suspended in a medium, like air or water. Things that aren’t “smelly” in the air *are* smelly in the water, because the water transmits chemicals much more effectively.

Fish have big nasal cavities called **nares**. Although the nare openings on a trout’s snout look much like our nostrils, they are not quite equivalent. Our nostrils are used for both smelling and breathing, so they are connected to our lungs. Since trout use gills instead of lungs to breathe, the nares are closed sacs that are used only for detecting odors. They do this job very well: salmon can smell certain chemicals on human hands at 1 part per 80 billion (like 1/80 a teaspoon in an Olympic pool). Trout also use smells to communicate with each other; females use chemicals called pheromones, in the mucus on their skin, to tell males when they’re ready to spawn.

Fish also have a sense organ, called the **lateral line**, unlike anything humans possess. It is a “distant touch” sensor that detects pressure waves, or vibrations. The lateral line is what allows a fish to maintain its position in a school without bumping into other fish. Look closely at a fish, or at a good drawing of one, to see the lateral line. It is visible as a line of special cells (called neuromasts) that run all the way from head to tail. Use **Activity #12, Which Side Are You on? (p. 55)** to help compare and contrast the lateral line with our sense of hearing, and to apply students’ new knowledge of trout biology to fishing tactics.

Life Cycles

Understanding the details of trout and salmon life cycles is essential if we are to protect them. Certain life stages are especially vulnerable to disturbances, and dams and other physical barriers can be particularly deadly to migratory species. Many trout, and

some landlocked salmon, spend their whole lives in fresh water. Others are born in fresh water and later migrate into salt water, before returning to fresh water to spawn. This type of life cycle is called **anadromy**. It will be explained in detail in the second part of this section.

The Basic Trout Life Cycle

Depending where they live, trout will reproduce at different times of the year. Two to four weeks before spawning, male trout ready themselves by undergoing a set of physical changes. Colors become more intense (i.e. a sockeye's red color or a brook trout's brilliant fins). A mature male also develops a **kype**, a hooked lower jaw with strong teeth. Closer to mating time, the female starts searching for a good site to build her **redd**, or nest. She will deposit her eggs in clean gravel that has quality water flowing through it, so that they get plenty of oxygen. When a female has found a suitable site, she uses her fins to cut her redd. She hovers over the site, scooping out a little depression. Then a male swims up beside her. Sometimes, **competition** between the males is fierce. They display their size and strength, and sometimes even bite each other. In addition to staving off other males, they need to impress the females they want to mate with. They do mating dances while the females work on the redds. Interrupted females will sometimes slap at over-eager males. When a female is ready, her mate swims up alongside her, and she releases her eggs while he releases his **milt**, which fertilizes the eggs. The female covers the eggs with gravel. Females usually repeat this process two or three times with different males, at different sites. This takes place over a couple of days.

Eggs develop and hatch as they incubate. About halfway through the incubation period, tiny trout come out of the eggs. The trout are not yet free-living; they still feed on attached egg sacs instead of foraging. This stage is called the **alevin**. Eggs and alevins are particularly vulnerable to environmental disturbances, because they cannot leave the redd to escape. Sudden sedimentation, e.g. from a big storm, can smother the young. **Anchor ice** (ice that forms on the bottom, rather than floating to the top) or very warm water can also kill the growing trout. Alevins stay in the redd until the egg sacs are digested. They then become **fry**. This process can take a long time, especially in very cold water. For fall spawners, it can take 8 or 9 months for fry to emerge.

Different species mature at different ages. Brook trout grow up in 1 or 2 years, but cutthroats need 3 or 4 years. What would be some advantages of a shorter life cycle? (Having a better chance of reproducing before being eaten.) A long one? (A chance to grow larger, and thus produce more offspring at one time.) When these full-grown trout get ready to spawn, the cycle starts all over again.

We'll talk at some length about migration between fresh and salt water later, but many non-anadromous salmonids still migrate. For a movement to be a true migration, it must be a cyclical movement with three elements: a fixed time period, the involvement of most of the fish in a population, and a definite destination. Many salmonids migrate from lake to stream (or the reverse), or from shallow to deep water (or the reverse). They might do it to feed, or to move from warmer to cooler water (or vice-versa). Some of these trips are quite substantial, but they are nothing compared to ...

The Sea-run Life Cycle: Lifestyles of the Fat and Anadromous

Before you go into the details of the anadromous life cycle, it might be helpful to pose the question, “Why be anadromous?” Migration can be dangerous; any coordinated movement exposes fish to intense predation (e.g. grizzly bears feeding on Alaskan salmon). There must be some great reward in the ocean to make it worth the risk.

The anadromous life cycle begins with eggs in a redd. The eggs hatch into **alevins**, tiny trout which can swim but cannot leave the redd. Alevins are nourished by an attached yolk sac. As they use up the yolk sac, they grow into **fry**, which feed more or less as adults do, and emerge from the redd. Anadromous fish usually spend 1-4 years in the lake or stream they were born in before migrating out to sea. When they are almost physically mature enough for the trip, they lose their parr marks and turn into **smolt**. Their colors change so that they will be camouflaged in the sea instead of in fresh water. Smoltification changes both appearance and body chemistry, since keeping salts and water in balance works differently in salt and fresh water.

Smolt migrate downstream into the sea, where they spend 2 or 3 years. There is much more food in the ocean than there is in freshwater habitats. While in the ocean, salmon mostly eat tiny shrimp-like creatures called krill (just like blue whales do). Anadromous fish attain their adult size while in the ocean. Because there is so much food in the ocean, anadromous fish get much bigger than landlocked ones. A “big” landlocked rainbow trout weighs about 5 pounds. Sea-run rainbows, called steelhead, are genetically near-identical, but they often weigh 25 pounds. A female salmon will lay approximately 1000 eggs for each kilogram she weighs, so there is a direct correlation between body size and fertility.

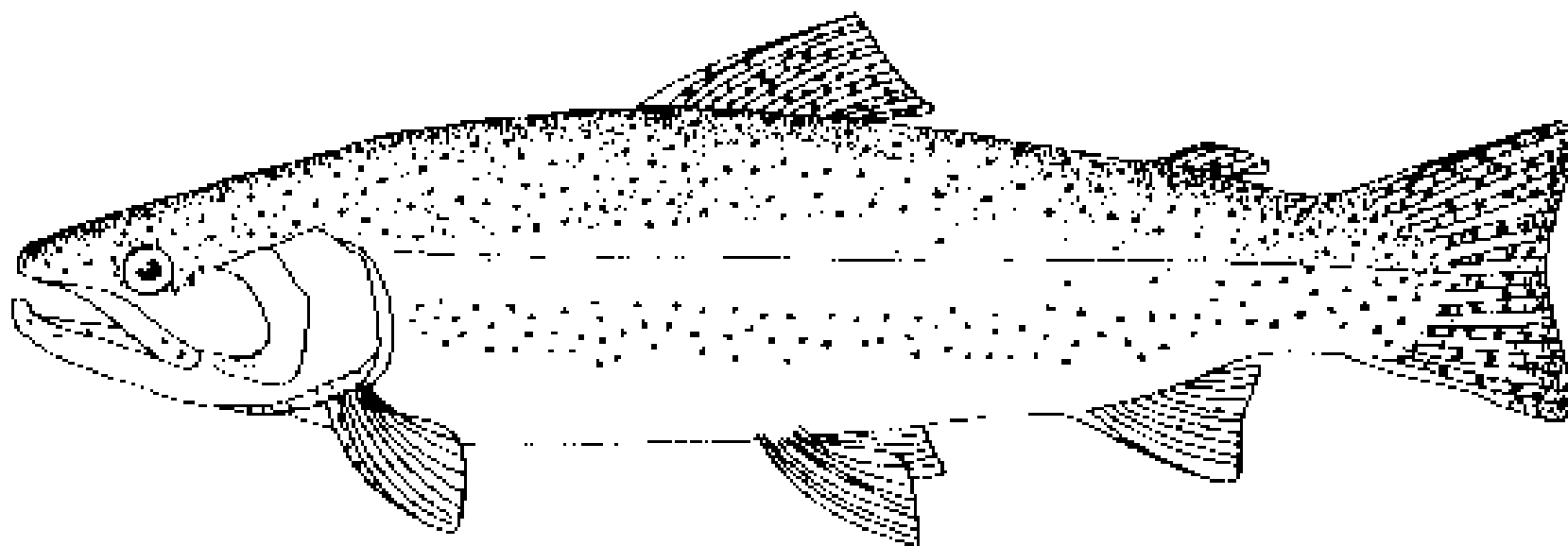
When salmon are nearly ready to spawn, their colors change to mating shades, and they adjust their physiology for a return to fresh water. Most mature salmon migrate back to the streams in which they were born, but scientists do not completely understand how they find their way home. Salmon definitely use the current and their sense of smell to find their way upstream, but exactly what odors they recognize is not known. It may be the smell of landlocked relatives or the unique chemical composition of the bedrock and runoff. Whatever smells salmon use as cues, it is clear that pollution in the native stream can be very damaging, since any change in chemistry equals a change in smell.

Migration can be very hazardous. Predators, diseases, and changing stream flows all pose obstacles. In addition, human development creates hazards with dams, pollution, development, and overfishing. From a redd of 1000 steelhead eggs, an average of only 1 individual survives to return to the home stream and spawn once. The trip itself is exhausting; salmon leap over waterfalls that would be impossible for an unhealthy fish to surmount. Some fish, like the Pacific salmon, spawn only once before dying. Their bodies decompose and enrich the streams in which their young are developing. All trout and char, and the Atlantic salmon, are capable of migrating and spawning 2 or 3 times. The typical lifespan of an anadromous trout is 3 to 7 years.

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The Trout Body



Trout Fill-In

Fill in the blanks with the names of the appropriate trout body parts. Are there any others you can think of, or internal parts that aren't shown on this drawing?

Adipose Fin

Anal Fin

Caudal Fin

Dorsal Fin

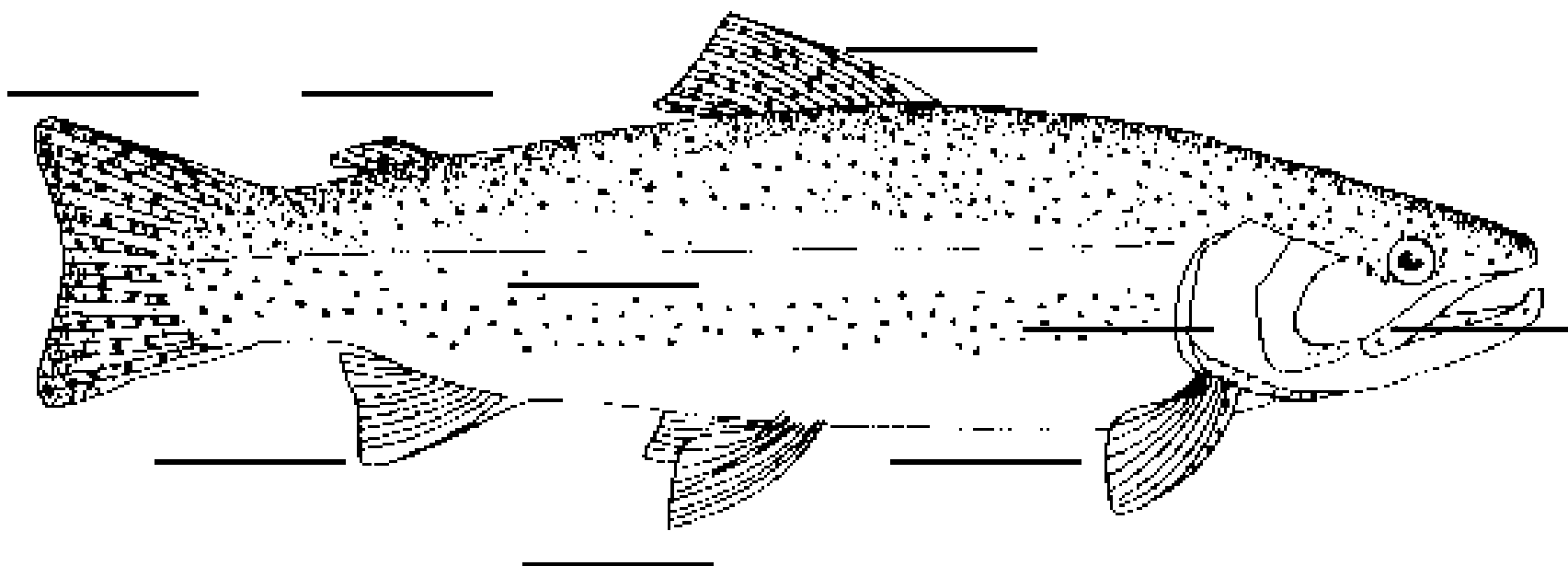
Mouth

Lateral Line

Operculum

Pectoral Fin

Ventral Fin



Color a Trout

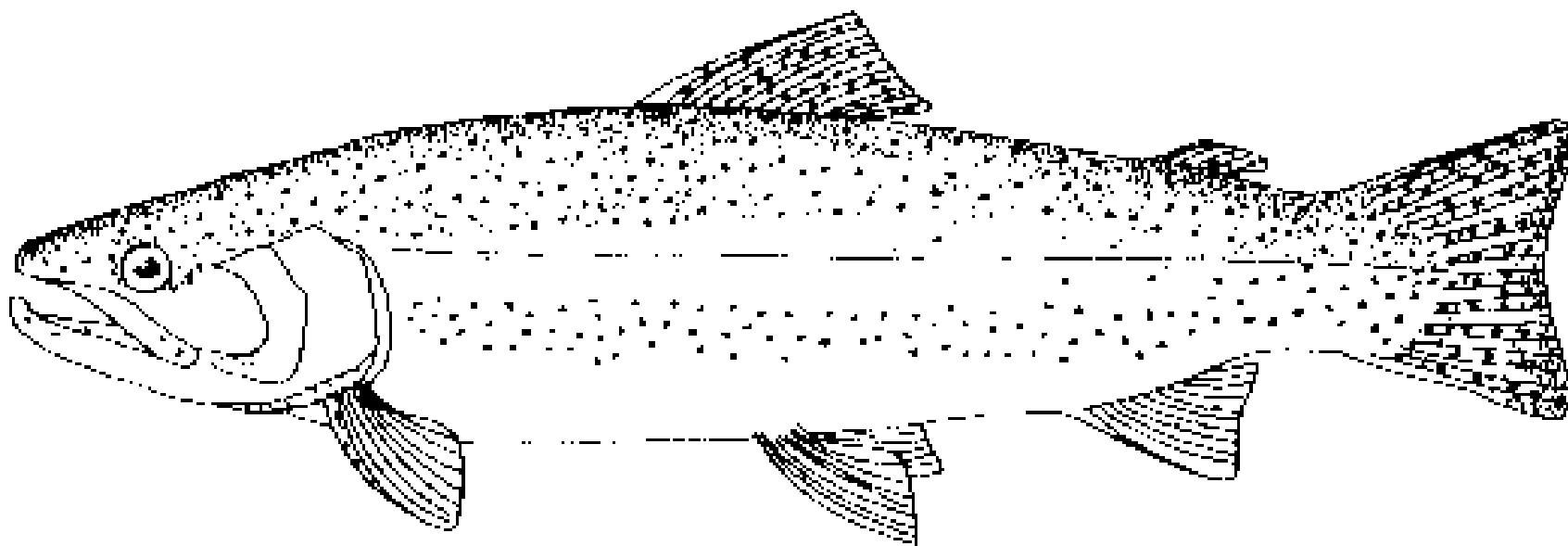
Draw, paint, or decorate this trout however you please. Below are a few suggestions for markings. Mimic a real species, or make up a fanciful new one.

Parr Marks

Spots (light spots on a dark background for char, dark on light for trout)

Vermiculations (the wormlike markings on brook or lake trout)

Spawning reds



Activity # 12, Which Side Are You on? How fish use the lateral line

Introduction

This game demonstrates how fish use the lateral line to locate their prey. It was adapted from Virginia Department of Game and Inland Fisheries Sportfishing & Aquatic Resource Education (2001). The game was designed with warmwater fisheries in mind, and in fact, trout use the lateral line more for sensing their environment and each other than for detecting prey, but the same basic principles will apply. It starts by demonstrating how humans locate sound sources and goes on to apply the lessons learned to fishing.

The **lateral line** is a special sense organ that trout use to “feel sounds.” They have ears just like our middle and inner ears, which allows them to hear sounds within the range we sense, but the lateral line allows them to hear sounds so low that we can’t hear them. Every sound is a vibration, but usually the **amplitude** of a sound wave is small enough that you hear it but don’t feel it.

The lateral line is made of a series of U-shaped tubes. Every time the water outside the tube vibrates, a tiny hair at the base of the tube wiggles, which sends a nerve signal to the brain. The brain translates the wiggle to figure out in what direction and how far away the vibration was produced. It only works at short ranges, less than 2 -30 feet from the fish. Fish that live in cloudy water, like bass and sunfish, often use the lateral line to locate their prey; trout are more likely to use it to maintain a distance from each other when schooling (like in a migration).

Time: 10-20 minutes

Ages: elementary school

Materials: a selection of lures (plugs, spinners, jigs)

Prep Work: none

Procedure, Part I.

The first part of this activity helps illustrate how our sense of sound helps us locate things.

1. **Tell everyone to close his or her eyes.** Tell kids that you are going to sneak around the room and snap your fingers. When they hear you do this, they should point in the direction of the sound source, but keep facing the same direction.
2. **Quietly move around the room and snap your fingers from varying locations in front, behind, and to the sides of the students.**
3. **After 4-5 snapping locations, discuss how the ear determines where sounds come from.** Being by asking the student how they determined where you were. Their obvious response will be that they “heard you.” Ask if the ear was equally effective at determining your location from all directions. In which direction(s) were the sound sources easiest to detect? Hardest? They will probably have noted that sounds

directly in front and behind them were the hardest to pinpoint, while sounds to the sides were easiest. Challenge them to explain why.

The reason is the way ears are positioned on the head; they are pointed to the sides. When a sound comes from the side it goes directly into one of the ears. The sound then comes around the head and into the other ear. The brain instantaneously calculates the difference in time that it takes the sound to get from one ear to the other and from that determines the position of the sound source. Sounds coming from the front or back enter both ears at the same time, making it more difficult to pinpoint the source's location.

Try to extend this lesson to trout anatomy—why would it be better to have two long lines of vibration-sensing cells, rather than a very localized sense organ?

Procedure, Part II.

1. **Arrange kids into a circle.** They should be arranged shoulder to shoulder. Welcome them to the pond they just made. Explain that in the pond there are two kinds of fish, the predator Largemouth Bass and the prey, Redbreast Sunfish (show pictures if available).
2. **Introduce one student into the middle of the circle. He/she will be the bass.** Inform the students that the water in the pond is dark and for our bass to find its prey, it will have to use its incredible sixth sense of vibration rather than sight. Have the bass shut its eyes or put on a blindfold. It will need to listen carefully for sunfish, especially wounded ones that are easier to catch.
3. **Explain that the rest of the students are the sunfish and that they make vibrations as they swim through the water.** Snap your fingers rhythmically to show what a sunfish flapping its tail might sound like. Then ask all the sunfish to snap (or clap) along with you at the same rate (but not synchronously). Also instruct them to stand in place.
4. **While everyone is snapping, explain to the group that in nature, predators often single out an animal that is weak or wounded, since it is easier to catch.** Ask them if they know how a fish can tell when another fish is weak, wounded, or sickly. A fish might swim fast, slow, or simply flutter. The vibrations emitted by this type of swimming are different from those of a healthy fish, and predators are quick to recognize it.
5. **Point at one Sunfish in the circle and have him/her change the pace of their snapping.** Tell the bass that it is up to him/her to locate (by pointing to) the wounded prey by listening for a different vibration in the water. Give each student a chance to be the bass and try to pick out several sunfish.
6. **Discuss how to apply this activity to fishing techniques:**
Do trout use the lateral line or vision more when sensing a dry fly? A streamer?
Is it easier to sneak up on a fish in flat or turbulent water?
What kind of lure would you want to use at night, or in the deep ocean?
Which do you think uses its lateral line more, a bass or a trout?

Activity #13: Salmon Farming Debate

There is a multitude of good online resources for salmon. Efforts to protect Pacific salmon are in the news as frequently as any wildlife issue in this country. This unit could be combined with the **Ch. 7, Human Impacts on Coldwater Resources** unit to elicit some good discussions about conservation policy and economics. Atlantic salmon farming is a particularly hot topic right now, as the relatively young industry is coming under a lot of fire because of the amount of organic waste it generates, the possibility of transmitting diseases to wild salmon populations, and the chance of farmed salmon escaping to compete with wild stock.

You might want to stage a debate on the merits and dangers of salmon farming. Divide students into two or more groups. Have them research the issue and defend a point of view. If you have a small group, one can represent an environmental group, and another can represent the salmon farmers and their families. Additional students might role-play Native American groups, politicians, commercial fishermen, and sport fishermen. Some resources to begin with:

- Environmental Media Services has links to a number of different sites about the environmental impacts of salmon farming at:
http://www.ems.org/salmon/salmon_farming.html
- Atlantic Salmon of Maine has produced a publication on the environmental impacts of their business: http://www.majesticsalmon.com/facts_ei.html

Chapter 6, Reading the Stream

Use with fishing skills **READING THE WATER** and **PRESENTING THE FLY**.

New Idea

- **Reading the Stream**

Activity

Activity #14: Find the Trout, p. 60

- o Handout: Find the Trout, p. 61

Introduction

Reading the stream means looking at a stream and predicting where trout will be found. Many anglers call it “thinking like a fish,” and indeed, to predict where trout will be, we have to think about their needs, and how they can fulfill those needs with minimal effort. Learning to read the water teaches not only fishing lessons, but also hydrology, biology and conservation.

Teaching Tips

Use this section to emphasize the link between learning science and catching fish! Ask leading questions to help students realize that they use principles of hydrology and biology every time they fish. Thinking about their own fishing experiences will teach science lessons they didn’t realize they already knew. We have not included instructions about fly placement or drift in this section, but they can and should be discussed here.

Reading the Stream

In order to catch fish, one needs to figure out where fish are and present the correct fly in a natural manner. In order to predict where fish will be, brainstorm a bit about what fish need. Trout live in a multitude of different habitats; they thrive in salt and fresh water, lakes and streams. The most basic, crucial requirements shared by all trout are water, food, and cover.

Water provides trout with food and cover. In order for a particular body of water to be appropriate habitat for trout, it must be cold and clean with certain chemical characteristics, namely

- Temperature between 40-68C
- Dissolved Oxygen (DO) above 6.5mg/l
- pH of 6-9 (relatively neutral)

Each species of trout or salmon has different specific needs, e.g. brown trout can tolerate warmer water than most, but bull trout need unusually cold water. One can make certain predictions about water quality just by looking at a stretch of water. For example, water that is fast, clean, and cold should be well-oxygenated, and a limestone creek is likely fairly resistant to pH changes.

Trout are generalist predators; they eat a number of different organisms. The fish and invertebrates that trout eat generally thrive in the same sort of habitats that are good

for trout. Being aware of invertebrate activity is an important part of reading the stream. Insects like mayflies often hatch around dawn or dusk, and every body of water has a characteristic hatch. Since trout become keyed into the foods they encounter most often, the flies an angler presents are determined by the things trout are already feeding on. Using a small dip net or turning over a few rocks is a good way to investigate what the trout you're after will respond to.

Cover is the last essential element of trout habitat, and thus of reading the stream. Cover is anything that shelters a fish; usually it is a stream bank or a submerged (partially or completely) log or boulder. Cover protects trout from predators, including larger fish and land animals.

When trout forage, or search for and eat their food, they balance these needs with **economy of effort**. They need to live in high-quality water and get plenty of food, but leaving cover or rising to the surface to feed introduces the risk of predation. Also, fast-moving water will have the most feeding opportunities, because invertebrates will drift past a trout at a faster rate than they would in slow water. Swimming in fast water has a cost, though; it takes energy. When anglers read different parts of a stream, they consider this balancing act to discover a trout's **lie**, or foraging site.

Friction, current seams, and depth are three features to look for in a pool, run, riffle, or curve. **Friction** is a force that resists motion. Friction can be exerted on water by the structures over which it flows. It slows water down, just as water slows you down when you try to run in the pool. Water encounters the most friction when it flows over an obstruction (e.g. a boulder) and near the bank or bottom of a stream. For this reason, big fish sometimes occupy very deep lies.

A **current seam** is a place where fast and slow-moving water meet. Seams make good lies because they allow trout to sit in the slow water with their snouts pointing upstream. This way, they see many of food items rushing past in the fast water, but they minimize their swimming effort by staying in slow water.

A submerged boulder or log is the first place most anglers learn to look for fish. The obstruction slows down water and creates an **eddy**, a slow, swirling area on the downstream side. Trout often hover in this slow water and wait for food to drift by on the seam. An eddy is also a good spot to occupy because the obstruction that forms it provides some cover.

An **undercut**, an area where the bank overhangs the water, is another good place to look for trout. The overhang provides shelter, but an undercut is also an indication of what's happening beneath the surface. Undercuts are usually formed on the outside of a **curve**, where fast-moving water cuts the channel more deeply than it does on the inside. There is usually a nice, deep lie at the bottom of the channel.

Pools are wide, deep sections of water. Trout sometimes rest in the slow water at the bottom of a pool. They tend to feed at the **head** or **tail** of the pool, because there is a constriction there to funnel food items together.

A **riffle** is an area where friction breaks up a stretch of water. Riffles are often caused by beds of small or medium-sized boulders.

Species preferences and interactions with other trout also influence where one will be. Trout are **territorial** animals, meaning that each has a specific area in which that he or she feeds. In general, a larger trout will be dominant over smaller ones. In a given stretch of water, the dominant trout gets the most productive lie, and the rest fill in the

spaces of decreasing desirability according to descending rank. Two trout feeding in the same stream would not necessarily find the same lie most desirable. If brown and rainbow trout coexist in a single pool, the brown trout will often hold on the bottom of the pool, while the rainbow prefers faster water. Also, a small trout might pass up a very productive spot for one that had better cover, whereas a less-vulnerable large trout would do better taking the more productive, dangerous lie.

An angler must also consider his presence as part of the stream environment. Trout will hide or stop foraging if they spot a predator or a fisherman. Trout might see fly line or shadows, and they can feel vibrations from careless wading or disturbed rocks. A beautifully clear, flat limestone stream is difficult to fish because trout there are easily spooked. Conversely, fishing at dusk is often productive in part because the low light makes it harder for fish to see anglers.

This is one reason that it is important to stop, look, and listen before one begins fishing a stretch of water. An angler should always approach a pool quietly and cautiously and stop some ways back from the bank. Take a few minutes to examine the scene, read the stream, and take in the scenery. Plan the order in which you will fish the different features, and then enjoy.

Activity #14: Find the Trout

Time: 20 minutes

Introduction

This quick activity gives kids a chance to practice their stream reading and fish-finding skills in a dry run, before they test them on the water.

Prep Work: collect materials

Ages: All ages

Materials (per student)

- Copy of **Find the Trout** handout, p. 61
- Pen or pencil

Procedure

Ask students to follow instructions on the **Find the Trout** handout (p. 61). Alternatively, students could draw their own pictures with colored pencils or crayons, creating a fantasy lake or stream with its own topographical features and food web. Have students return to their drawings after a fishing or field trip. What can they add?

Extensions

Discuss how to read a lake.

References

Butler, 1991
Cooper, 1999
Fausch, 1991
Thorbjarnarson, 2002

Find the Trout

- Label this stretch of water with as many different features as you can.
- Circle all the trout you can find. Draw more if you think there are other places you might find them.



Illustration by Richard Harrington

Chapter 7, Human Impacts on Coldwater Resources

New Ideas

- **Pollution**
 - Point Sources
 - Non-Point Sources
 - Handout: Land Use Conditions, p. 87
 - Handout: Physical Conditions, p. 89
 - Handout: Water Quality Conditions, p. 91
- **Habitat Destruction: Hydrological Change**
- **Introduced and Invasive Species**
 - Non-native Trout Species Introductions
 - Whirling Disease
 - Overhead: What in the Whirl is Whirling Disease?, p. 71

Activities

Activity #15: Color me a Watershed, p. 73

- Handout: Map A, p. 81
- Handout: Map B, p. 83
- Handout: Map C, p. 85

Activity #1: Stream Sense (From Ecological Concepts), p. 9

Activity #9: Water Quality Bioassessment (From Stream Life), p. 39

- Handout: Bioassessment Worksheet, p. 41

Introduction

This section is formatted a little differently from the others, because there is such a wide range of topics that one could cover. It is divided into four classes of issues, which are subdivided into a number of specific problems in coldwater conservation.

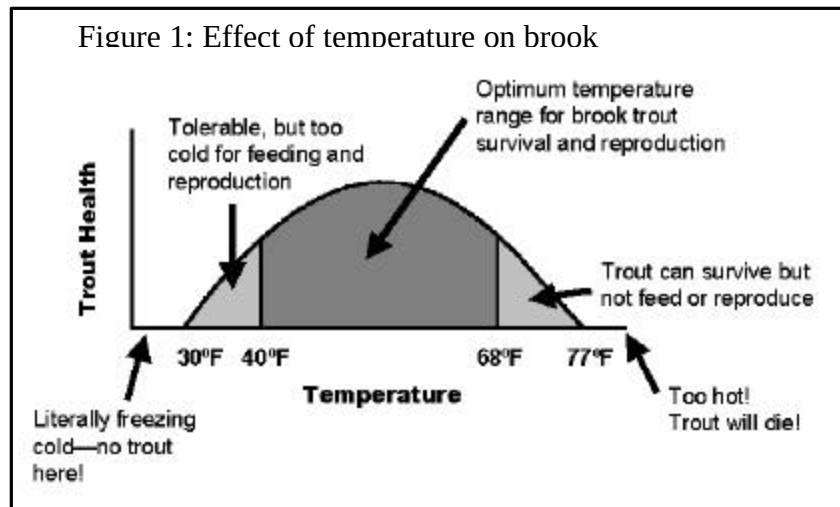
Your time will be limited, so pick an issue or two that hits close to your home river. You, or someone in your chapter, or a local fish and game official will be able to speak knowledgeably about it. Consider bringing in a guest speaker or organizing a field trip where students can see the problem first-hand.

Pollution

The word “pollution” makes a lot of people think of poison spilling out of a drainpipe into a stream. In fact, that isn’t always true: much pollution consists of substances that are harmless, or even nutrients, in appropriate doses, but that are deadly in high doses.

For any substance or environmental factor, an organism can tolerate a certain range of levels (illustrated in Fig. 1). Outside this range, it will die. Within this range, there is a range of tolerance, where it can survive but perhaps not grow or reproduce, and an optimum range, in which it can survive, grow, and reproduce. For example, a brook trout can survive temperatures as low as freezing and as high as 77°F. Outside this range, the trout will die. Their optimum temperature is between 40°F and 68°F. Within this range, they will feed, grow and reproduce. In very low temperatures (30-40°F) or the

highest ones they can tolerate (68-80°F), the trout will survive, but they will not feed or reproduce. (SmokiesWeb 1997-2001) The diagram shows the relationship between temperature and brook trout health. We could draw a similar one for any component of the organism's habitat, such as pH or dissolved oxygen.



Point and Non-point Sources of Pollution

It is important to understand the difference between **point sources** and **non-point sources** of pollution. A point source is a single, identifiable source of pollution, like a leaking gas tank or an outlet pipe from a factory. Spills and negligence that cause point source pollution can be extremely deadly to trout and other aquatic organisms. Fortunately, point source pollution is fairly easy to control if people are conscientious and committed. Federal laws like the Clean Air and Clean Water acts also help.

Non-point source (NPS) pollution cannot be pinpointed at a single source, so it is much more difficult to control. NPS pollution is much more difficult to control. Sources are created every time humans disturb land, and much of the pollution isn't "poison." Which is more likely to provoke public outrage, a new shopping mall, or a factory spewing soot from its smokestack? Of course the shopping mall is considered desirable, but runoff from its construction and maintenance may turn out to be very damaging to the surrounding watershed. Much NPS pollution comes from land use practices that aren't necessarily considered irresponsible. **Nutrients** and **sedimentation** are the most important non-point pollutants, and in appropriate doses, both are parts of healthy watersheds and ecosystems. In general, the most important NPS's are agriculture, urbanization, forestry, and stream bed channelization.

Agriculture causes erosion and increases certain types of harmful waste. Before crops are planted, feedlots are built, or cattle begin grazing, native vegetation is always cleared from the land. This reduces the watershed's capability to deal with runoff. As **Activity #6, Just Passing Through (p. 24)** illustrated, plants' ability to help soil capture water is crucial. When vegetation is cleared, soil cannot absorb as much water, runoff velocity increases dramatically and erosion increases. In addition to washing away that soil that farmers need, this causes a great deal of siltation, or sediment deposition, in watersheds. Siltation increases turbidity, which has a number of deleterious effects on trout.

Turbidity increases water temperature. Just as a black car heats up faster than a white one, turbid (cloudy) water absorbs and holds more heat than clear water. If the sun shines on a stream made silty by agricultural runoff (water that has run over fields that are under grazing or cultivation), it will get hot faster, and stay hot longer, than a clean one. Trout that are uncomfortably warm will stop feeding and may not reproduce. Temperature also affects **dissolved oxygen (DO)** levels. Fish need DO in the water in which they swim because they breathe with gills. DO levels depend on a number of factors, but the ideal gas law (an important idea in chemistry) states that the colder a liquid, the more gas can be dissolved in it. Hence, the colder a body of water, the more dissolved oxygen it can contain. Trout need a lot of DO relative to other freshwater fish. DO is expressed in milligrams per liter. Trout and insects that need high-quality water require at least 6.5mg/l, but carp and channel catfish can tolerate levels as low as 2mg/l. Cutting riparian vegetation not only increases temperature through turbidity, it also reduces shade. This both warms the water and makes trout more vulnerable to predators. This is why so many TU habitat restoration projects start by re-planting riparian vegetation.

Agricultural runoff can also impair DO levels through a process called **eutrophication**. Eutrophication happens because manure and fertilizer are plant nutrients, whether they are on land or in the water. Excessive nutrients cause “blooms” of algae, microscopic aquatic plants. This has two major effects: first the algae can block the sunlight needed by larger plants. Those larger plants die, which decreases the cover available for animals like trout. Secondly, this huge amount of algae will eventually die off. When algae die, they are digested by aerobic bacteria that consume oxygen. The same is true of the bacteria that consume manure itself. These two factors combine to make lakes or rivers inhospitable to fish, who have nowhere to hide and no oxygen to breathe.

Siltation is also a problem apart from its effects on temperature and dissolved oxygen. By definition, silt settles on the bottom of a stream or lake. Silt forms a layer over the gravel in which trout build their nests. It covers trout eggs and works its way into the spaces between them, which can suffocate the eggs and kill them by the thousands. Large trout are rarely affected by silt on their gills, but alevins and fry can be killed by such direct suffocation. The **benthic** insects that trout eat are much more likely to be killed than the trout themselves. Siltation can easily starve trout to death. Unfortunately, changing harmful practices will not fix matters right away. It may take 5-10 years after reducing siltation for deposits to wash away and restore the stream to its previous quality.

Silt is not the only substance that washes off of agricultural lands. Fertilizers and manure also contribute to eutrophication, and bacteria in livestock feces can be very poisonous to humans. Herbicides and pesticides, which are also washed into streams from fields, kill aquatic organisms.

Urban development causes many of the same problems as agriculture. Nearly all urban and suburban space is covered with impermeable materials like concrete and asphalt. During dry weather, these surfaces decrease the rate at which watersheds are recharged. When there is a storm, two problems arise: runoff is unnaturally abundant, and it is full of toxins. Under dry conditions, oil, dust, gasoline, cleaning products, fertilizers, and lawn and garden herb/pesticides are deposited, little by little, onto urban

surfaces. When it rains, these substances are washed into storm drains, which often receive little or no treatment before being released into watersheds. The problem is exacerbated by the fact that development often fills in wetlands, which are one of nature's most vital wastewater treatment mechanisms. Of course pristine watersheds experience additional runoff during storms, but developed ones may have trouble withstanding an average storm event, especially if sewers are not well-maintained. Urban streams and canals often swell noticeably following a moderate storm, and they often smell bad. The sulfurous smell coming from an urban creek after a storm is a combination of anaerobic bacteria digesting organic waste, fossil fuel runoff from roadways, and sediments washed off lawns, pavement, and construction sites.

In order to deal with the increased peak flows that come from development, urban streams are often channelized. **Channelization** means attempting to increase the amount of water that a stream can handle at peak times. It is supposed to control flooding in areas where people live and work. It has also been used in wetland areas to control mosquitoes. Channelization always damages habitat by increasing water velocity and removing cover, but it does not always meet the development goals for which it is used.

Channelized streams flow slowly when volume is low, which causes large amounts of sediment to be deposited, rather than washing downstream. This quickly fills channels in and decreases stream capacity. Channelized streams often continue "trying" to follow their original courses, which means that they erode quickly and are costly to maintain.

Forestry is another NPS that can have profound effects on native trout fisheries. Logging is often located in the drainage of a small tributary, rather than in the main branch of a trout stream, but its downstream effects can still be severe. There are few chemical pollutants in logging runoffs, although it can contain fossil fuels from trucks and other machinery. Logging dramatically increases siltation, which can smother young trout and their eggs. In addition to the turbidity increases that happen when vegetation is removed, cutting down trees decreases the shade that a stream receives, which lets the sun warm it directly. It also shades out and kills aquatic vegetation, which fish need for shelter, and as habitat for their invertebrate prey. It also removes the terrestrial insects that form an important component of their diets, especially in the summer and fall. In addition to the effects of siltation that were discussed in the agriculture and urban runoff sections, siltation from logging can also fill in pools, which makes streams flow faster. This has a fitness cost to fish, which must swim constantly against a current, instead of taking advantage of the slower water provided by pools. The roads that are cut into woodlands for forestry are a large part of the problem; some estimate that they are responsible for 90% of the increase in siltation that comes with logging. For this reason, the number of trees cut down is not necessarily the best indicator of logging's impact on a trout stream.

Especially in the eastern United States, **acid rain** has been a major problem for trout fisheries. Acid rain is caused by byproducts of burning fossil fuels. Fossil fuels are burned in cars, factories, and power generation plants. Sulfur dioxide (SO₂) and nitrous oxide (NO_x) are the primary offenders. These wastes move up into the atmosphere when coal, oil, and gas are burned. When they combine with rainwater, they form acids. These acids are deposited on watersheds when it rains. Depending on the substrate (rocks or soil) under a watershed, the effects of acid rain can be more or less severe. In the

Northeastern US, where the soil buffering capacity is poor (it cannot neutralize acid effectively), the pH of certain lakes has dropped below 5. A neutral pH, the one preferred by trout, is 7. The pH scale is logarithmic, meaning that a one-point difference actually stands for a ten-fold difference in acid concentration. Thus, a lake with a pH of 5 is 100 times more acid than a neutral one. Low pH is directly toxic to fish, and it also leaches aluminum out of the substrate. This aluminum is poisonous, and in addition, the effects of aluminum + low pH is worse than the sum of those effects (this is called **synergy**, combined effects greater than additive effects). Some lakes in Canada and the Adirondacks have been rendered sterile by acidification. The problem would be even worse if not for the fact that brook trout, the species native to the area worst affected, are less susceptible to acid rain's effects than are rainbow trout. Lakes can be helped with band-aid solutions like liming (adding chemical buffers), but decreasing SO₂ and NO_x emissions are the most important long-term measures we can take to stop acid rain.

In Pennsylvania and the Smoky Mountain states, Acid Mine Drainage (AMD) is another major source of acidification, as well as heavy metal and cyanide pollution. Because coal mining and trout fishing are both important resources in Pennsylvania, the state has published some excellent resources on the problem and its solutions. Good resources are:

- the USGS web site, <http://geology.er.usgs.gov/eastern/environment/drainage.html>
- and the Pennsylvania State Department of Environmental Conservation http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_AMD.htm.

Dams, Trout, and Salmon Migrations

People use dams to prevent floods, regulate flows, and generate power. The lakes they create also store water for urban uses and agriculture, and are sites for recreation. In California, which has dams in every major watershed, 80% percent of the captured water is re-routed to agriculture, 20% goes to urban uses. (Thorbjarnarson, 2002) Dams in California and the rest of the west have enabled urban centers like Los Angeles and Phoenix to boom, and have made eastern Washington and central California important agricultural centers. Unfortunately, dams are extremely damaging to trout and salmon populations. In California, Oregon, and Washington, dams have damaged, and sometimes completely destroyed, rich salmon fisheries.

Many people know that dams harm salmon, but dams also pose risks to non-anadromous trout species. Dams alter natural sedimentation patterns and trap 90-100% of sediment in the reservoirs they create. This creates abnormally warm, silty water above the dam. It prevents healthy levels of silt from traveling below the dam, which causes excessive erosion, and it keeps gravel from flowing to trout that need it for their nests. Finally, maintaining dams to prevent a dangerous breach is expensive, and even so, they do not last forever. One of TU's current projects is removing aging, smaller dams in New England. The Kennebec Chapter was heavily involved in the effort that eventually brought down the Edwards Dam on Maine's Kennebec River. Read about it at http://www.tu.org/small_dams/removal/3b-removal_kennebec.html.

For anadromous fish, dams are a deadly barrier. In addition to damaging spawning beds, they physically prevent fish from migrating up to their ancestral home

streams. In response to pressure from angling, environmental, and Native American groups, many dams have fish ladders, but they are generally not as effective as hoped.

The conflicts between dam users and salmon supporters are always complicated. It is difficult to measure the true economic impact of a dam, and different groups place very different values on wild salmon populations. The Snake River is one area where the fight over salmon habitat has been particularly intense. Before all the dams and diversions took place, over 1.5 million salmon ran in the Snake annually. Some Idaho farmers and power users say that they need the dams, but many environmentalists dispute the contribution that the dams really make to farming and power in Idaho. There is no denying the fact that the dams have damaged salmon populations so badly that the Coho salmon there disappeared entirely in 1986. The Snake River Sockeye salmon was listed as endangered in 1991, and in 1998, only two made it past the Granite Dam, which blocks the upstream migration of adult salmon and also keeps smolts from migrating downstream and out to the ocean. Instead of a fish ladder, smolts trying to pass the Snake River's Granite Dam are loaded onto big Army Corps of Engineers trucks and driven past the dam. This program has proven expensive and has not been the boon to salmon populations that planners had hoped for. Today, a number of environmental groups, including Trout Unlimited, are campaigning to breach the lower Snake River dams. Good places to learn more are

- <http://www.tri-cityherald.com/dams/snakesearch/kids.html> This site features "In Search of the Snake," a very detailed account of different players in the Snake River debate, that is geared specifically towards kids. Unlike some kids' sites, it is full of useful information and would be informative for most adults, too.
- <http://www.wildsalmon.org/>
- <http://www.tu.org/salmon> and <http://www.snakeriversalmon.org/> both link to Trout Unlimited's Snake River Salmon website

Discussion Questions

- Which is harder to control, point or non-point source pollution?
- What is the most abundant source of pollution in our area? How could we reduce it or encourage others to reduce it?
- Can we see evidence of pollution in our local waterways? Do our scientific tests confirm our suspicions?

Non-native Trout Introductions

Because trout are such prized gamefish, anglers who come to a new place often bring their favorite species with them. Brook trout are only native to northeastern North America, through the Great Lakes, and south along the Appalachian Mountains to Georgia, but they are now found all the way on the west coast, in the Sierra Nevada. Likewise, brown trout were introduced to the Americas from Europe in the late 1800s, and rainbow trout are only native to the Pacific slope of California and the Northwest. Non-native trout damage native populations by competing with them, but also by hybridization. Rainbow trout are closely related to cutthroat, golden, Gila, and Apache trout, and in many places, hybridization from introduced rainbows is much more of a

threat to native populations than competition. In some places, rainbow trout have hybridized with native trout, like the New Mexican Gila Trout, to the point where the native population is classified as endangered.

Stocking hatchery trout can also damage wild trout and salmon populations. In some places, people feel that stocking is necessary to maintain some population of trout. Because of overfishing, dams, forestry, and pollution, 80% of Columbia River drainage salmon come from hatcheries. Policy makers and anglers sometimes reason that a large population of hatchery fish is better than a small population of native ones. However, hatchery fish are less genetically diverse than native populations, which makes their populations more vulnerable to diseases, and they can also introduce diseases to native trout populations.

Whirling Disease

Not every introduced or invasive organism is big enough to see. You have probably heard about West Nile Virus, a very serious human disease. It was brought to this country from Israel around 1995. Humans are not the only species at risk from introduced diseases. Trout in the United States are suffering from whirling disease, a fungal infection first discovered in the U.S. in Pennsylvania in 1956.

Whirling disease is caused by a microscopic fungal parasite called *Myxobolus cerebralis* (Mc). Mc passes through two hosts during its complex life cycle. Follow along with the “**What in the World is Whirling Disease?**” overhead (p. 71) while you explain the parasite’s life cycle. Mc spores on the silty bottom of a river or lake are ingested (eaten) by tufibex worms. The spores change into the *traictinomyoxin*, or TAM form, while they are inside the worms. The TAM is the infective stage of the fungus; it is shaped like a little grappling hook in order to enter the trout body through the skin. TAMs can exist inside the worms, or free-living in the water. They are transmitted to trout in two ways: trout eat the worms, or free-living TAMs enter through their skin. TAMs move into the trout’s head and turn back into spores. Spores are released back into the water when the fish dies or is eaten by a predator.

Once TAMs are inside of trout, they cause cartilage and spinal deformities. The tails of infected fry turn black and kinked. Since whirling disease causes cartilage damage, young trout are worse affected by the disease. (Cartilage turns into bone as trout grow.) The “whirling” motion for which the disease is named is caused by pressure to nerves. The disease does not directly kill trout, but young ones can suffer crippling spine and mouth deformities that make it impossible to feed adequately or reproduce. If generations of trout cannot reproduce, their population will eventually die out. In addition, whirling disease makes trout more susceptible to stress, so that even catch and release fishing can be dangerous to them.

Whirling disease was introduced to the US from Europe. It has been found in 22 different states, and also in trout populations in South Africa, the former USSR, and New Zealand. The disease was probably introduced by infected hatchery fish, and some are concerned that it is still being spread this way. Scientists all over the country are working on solutions to the problem. It may be impossible to eradicate the spores, but stream management practices hold promise. Different trout species are not equally susceptible to whirling disease. Rainbow and cutthroat trout are the most susceptible, so Montana and Colorado have been especially hard-hit. Brown and lake trout can be infected with

the fungus without getting sick. Scientists are looking at this information to figure out whether there might be a genetic solution to the disease, or if the difference is just related to factors like the temperature at which different species spawn.

In any case, we know a few things about managing the disease. First, the tubifex worm host lives in silt, and managing the worm will certainly help the cause, so it is more important than ever to control NPS pollution. Secondly, responsible angling practices will help control the spread of spores from infected to uninfected watersheds.

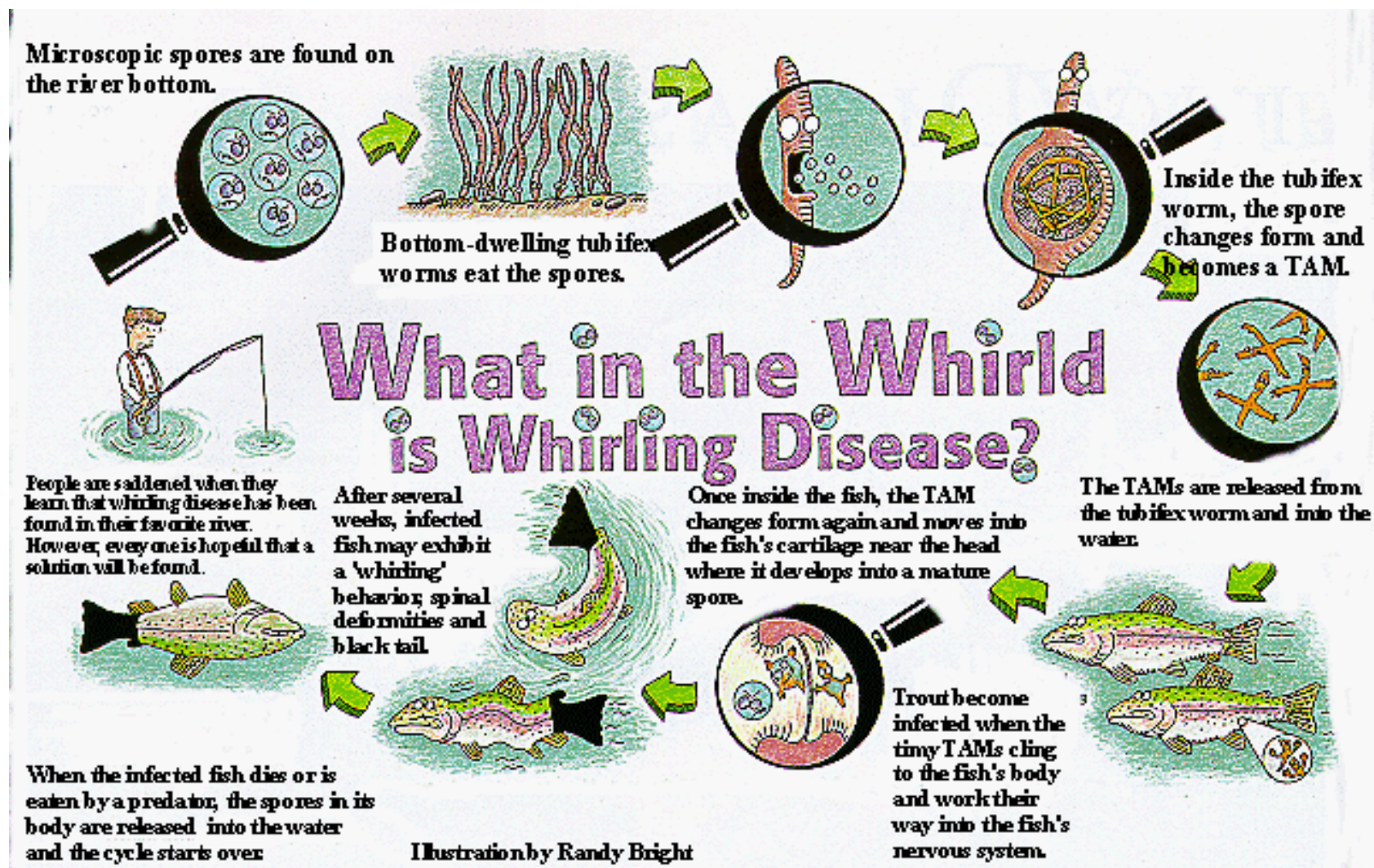
- Clean boots, waders, rods, and tackle before moving from one body of water.
- While common sense will keep TAMs from being spread, the spore is much hardier.
- A strong (50:50) solution of household chlorine bleach will kill the spores, but one must rinse very carefully to avoid damaging boots and waders. In addition, chlorine is quite toxic itself and should be diluted thoroughly before disposal.
- A better option might be to rinse equipment with nearly-boiling (200°C) water.
- Young children should not disinfect with bleach or hot water; older ones should be well-supervised

Discussion Question

- Investigate news stories about invasive species that have made recent headlines, or about aquatic invasive species that made the news in the last 20 years. What technological advances have encouraged the spread of invasive species? What are some ways to eradicate them? What are the pros and cons of different methods?

Extensions

- **Activity #13, Salmon Farming Debate (p. 57)** would certainly be pertinent to this discussion.
- **Activity #1, Stream Sense (p. 9)**
- **Activity #9: Water Quality Assessment (p. 39)**
- Taking the “Land Use Conditions,” “Physical Conditions,” and “Water Quality Conditions” posters on a field trip or **Activity # 8, Stream Safari (p. 35)** can help identify non-point sources of pollution in your area.
- A multitude of good layperson’s books on environmental science are available and would be good fodder for discussion in a long-term or school-based program.
 - Richard White’s book *The Organic Machine* is an environmental and cultural history of the Columbia River and the people who use it. It is appropriate for advanced high school and older students.
 - Rachel Carson’s *Silent Spring*, published in 1962, is one of the first documents credited with starting the environmental movement. Middle school and older students could read it.
- State Department of Wildlife, Fish and Game, or Department of Environmental Protection agencies usually have websites that are great sources of information about local issues. Most of these organizations will, with plenty of advance notice, happily send a representative to your program.



Activity #15: Color Me a Watershed

Introduction

Maps are often used to show landforms and political boundaries, but they can also illustrate land and resource use. In this activity, students investigate how land-use changes that accompany development can affect watersheds. Resource managers and policymakers do this all the time. They map watersheds in order to show what areas are likely to be impacted by floods, extrapolate growth patterns, and help make planning decisions. An historical sequence of photographs or maps can illustrate population growth and settlements over time and help plan for the future. Changes in land use can have dramatic effects on a watershed. Parking lots and homes absorb far less water than forests and wetlands. These sorts of changes increase runoff and reduce aquifer recharge.

This activity introduces students to the sorts of maps and data that these policymakers use. It illustrates how comparing past and current land use practices and studying maps can help resource managers make good policy decisions.

Time: 1 ½ hours

Ages: high school and older

Materials

- For Option I
 - o Copies of Maps A, B, and C (p. 81, 83, 85)
 - o Colored pencils
- For Option II
 - o Copies of Charts 1 and 2 for each student (p. 77)
 - o Copies of Answer Keys 1 and 2 (p. 79)
 - o Calculators
- Maps and photographs of community, past and present (optional)

Prep Work: 10 min. to collect materials

Procedure

Before you start, provide students with copies of *maps A, B, and C*. Explain that they are aerial views of a single watershed taken over a 100-year period. Ask them to look at the key and designate a different color for each land use. Have them color in each map with the same color scheme

Option I

1. When students finish coloring, have them compare (qualitatively, without math) the sizes of the different areas on each map and among maps. Ask them to compare plant cover and land use practices in each of these periods. They may note changes in croplands, forests, grasslands, wetlands, urban land uses, etc.
2. Discuss one or more of the following questions:
 - What happens to the amount of forested land as you go from *Map A* to *Map C*?

- Which map has the most land devoted to human settlements?
- Where are most of the human settlements located?
- What effect might these human settlements have on the watershed?
- Would you have handled development differently?

Option II

1. After coloring, have students determine the land area of each of these maps. Each unit in the grid represents 1 square kilometer (km^2), and the total area of each map is 360km^2 .
2. For each map, have students calculate how much land area is occupied by each type of land coverage.

- **Sample calculation:** to find the area of forest land 100 years ago, count the number of squares representing forest land in *Map A*. There are 189 squares, or **189km^2** of forest. Since the total land area was 360km^2 (given), the percentage of forested land was $189\text{km}^2 \div 360\text{km}^2 = .525$, or **52.5%**. (Answers in Answer Key 1, p. 79).

3. Tell students that the watershed has received 5cm of rain. What is the volume of rain that has fallen over the entire watershed? Over each land use area? (Of course rain does not normally fall evenly over a large area; assume that 5cm was the average over the entire watershed.)

- **Sample calculation:** to find the volume of rain falling on the forest 100 years ago, multiply the forest area by the rain depth.

First, convert 189 km^2 to m^2 and 5cm to m so that the units can be multiplied:

$$\frac{189\text{ km}^2}{1\text{km}^2} \times \frac{1000\text{m} \times 1000\text{m}}{1\text{km}^2} = 189,000,000\text{m}^2$$

$$\frac{5\text{cm}}{100\text{cm}} \times \frac{1\text{m}}{100\text{cm}} = 0.05\text{m}$$

Then multiply:

$$189\text{ km}^2 \times 5\text{cm} = \mathbf{9,450,000\text{ m}^3} \quad (\text{Answers in Answer Key 2, p. 79})$$

4. Discuss changes in land coverage represented in *Maps A* through *C*. Ask students if they think the amount of runoff would increase or decrease.
 - Discuss the following questions in addition to those listed in Option 1.
 - Which absorbs more water, concrete or forest (or wetlands or grasslands)?
 - Which map represents the watershed that is able to capture and store the most water?

- What problems could arise if water runs quickly over surface material, rather than moving slowly or soaking in?
 - How might the water quality of the river be affected by changes in the watershed?
5. Using the information from the maps and the runoff percentages from Chart 2, have students calculate the amount of water each land area, and each watershed, does not absorb.

- **Sample calculation:** to calculate the amount of water that is not absorbed by the forest land on *Map A*. Simply multiply the amount of water that fell on that land by the percent runoff given on Chart 2
- Find 20% (from Chart 2) of 9,450,000 m³ (calculated above, Option II, #3)
 $9,450,000\text{m}^3 \times 0.20 = \mathbf{1,890,000\text{m}^3}$ (Answers in Answer Key 2)

NOTE: the figures for percent runoff are abased on hypothetical data. To determine how much water is absorbed by surface material, one needs to know soil type and texture, slope, vegetation, intensity of rainfall, etc. In addition, many farms and urban areas practice water conservation measures that help retain water and prevent it from streaming over the surface. The information in the chart is only intended for practice and comparisons.

Discussion

Have students summarize how changes in the land affect the quantity and quality of runoff in a watershed. Discuss land use practices in the community and how they may affect water discharge in the watershed.

Extensions

It would be exciting to use land use maps or GIS pictures of a watershed that students have actually studied, or the one they live in. Such materials might be available from a few different sources:

- University and public library map collections
- A nearby university (departments of forestry, urban planning, environmental science, etc.)
- County agencies, city planning agencies, or irrigation districts

Measuring different uses and doing the math on a real map or picture might entail a lot of labor and tedium, but just looking at the changing distribution of land uses should be fodder for a lot of discussions. Think about the same sorts of questions that were asked in Part II

Adapted from Project WET *Curriculum & Activity Guide*, “Color Me a Watershed,” p. 223-231

Chart 1: Area of Land Coverage

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage	km²	%	km²	%	km²	%
Forest						
Grassland						
Wetland						
Residential						
Agriculture						
Stream						

Chart 2: Volume of Rain and Volume of Runoff

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage and % runoff	volume m³	runoff m³	volume m³	runoff m³	volume m³	runoff m³
Forest 20 % runoff						
Grassland 10 % runoff						
Wetland 5 % runoff						
Residential 90 % runoff						
Agriculture 30 % runoff						
Total runoff						
Total runoff plus stream discharge (5,550,000 m³)						

Answer Key 1: Area of Land Coverage

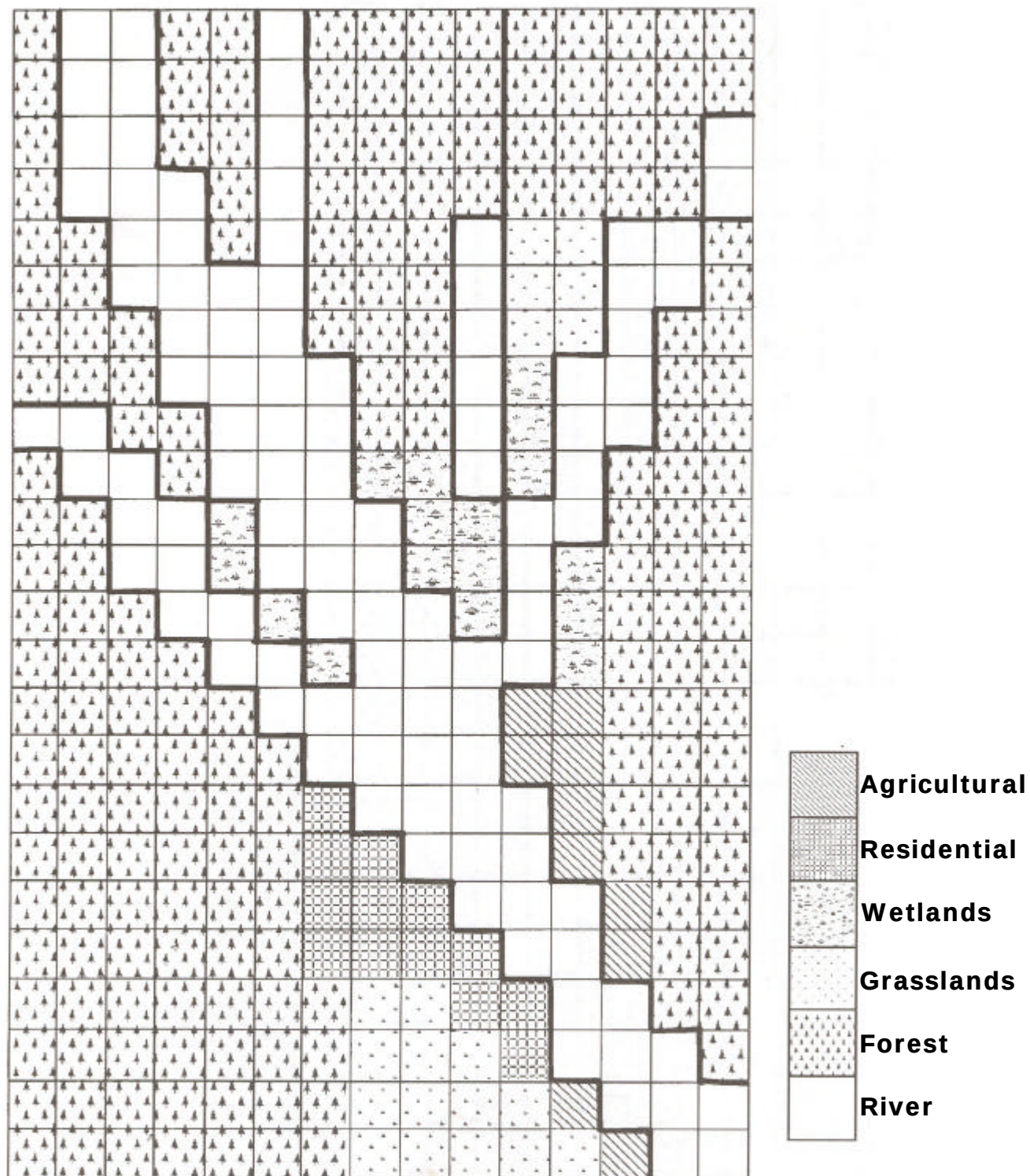
	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage	km²	%	km²	%	km²	%
Forest	189	52.5	162	45	111	30.6
Grassland	20	5.6	4	1.1	6	1.7
Wetland	17	4.7	23	6.4	5	1.4
Residential	13	3.6	33	9.2	59	16.4
Agriculture	10	2.8	27	7.5	69	19.1
Stream	111	30.8	111	30.8	111	30.8

Answer Key 2: Volume of Rain and Volume of Runoff

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage and % runoff	volume m³	runoff m³	volume m³	runoff m³	volume m³	runoff m³
Forest 20 % runoff	9,450,000	1,890,000	8,100,000	1,620,000	5,550,000	1,110,000
Grassland 10 % runoff	1,000,000	100,000	200,000	20,000	300,000	30,000
Wetland 5 % runoff	850,000	42,500	1,150,000	57,500	250,000	12,500
Residential 90 % runoff	650,000	585,000	1,650,000	1,485,000	2,950,000	2,655,000
Agriculture 30 % runoff	500,000	150,000	1,350,000	405,000	3,450,000	1,035,000
Total runoff	12,450,000	2,767,500	12,450,000	3,587,500	12,450,000	4,842,500
Total runoff plus stream discharge (5,550,000 m³)		8,317,500		9,137,500		10,392,500

Map A

100 years ago

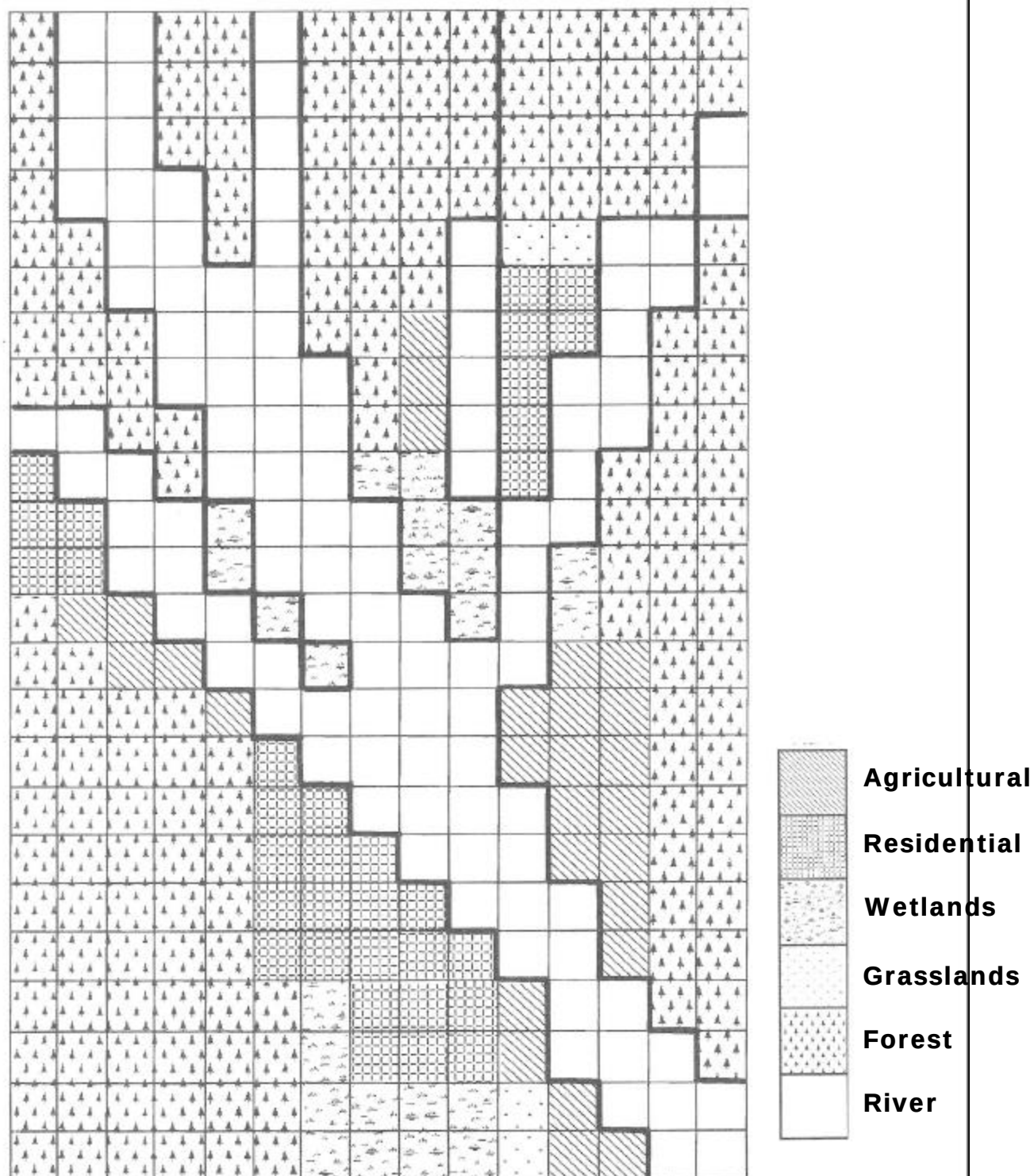


Each square represents 1km².

Adapted from Project WET "Color Me a Watershed"

Map B

50 years ago

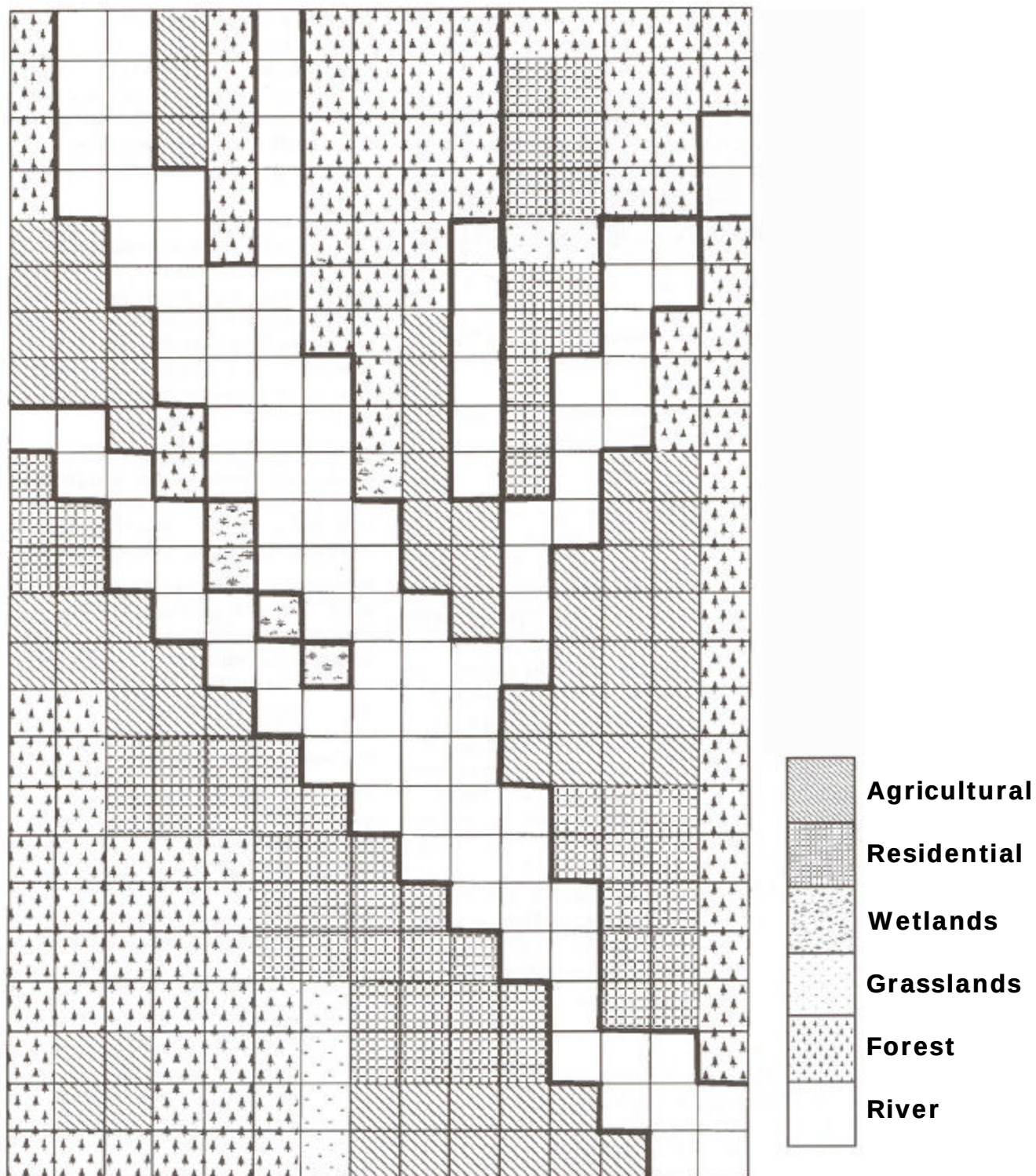


Each square represents 1km².

Adapted from Project WET "Color Me a Watershed"

Map C

Present



Each square represents 1km².

Adapted from Project WET "Color Me a Watershed"

Land Use Conditions

LAND USE CONDITIONS	POSSIBLE ASSOCIATED PROBLEMS	POSSIBLE ASSOCIATED CAUSES
AGRICULTURAL		
Crop Production	Chemical runoff—pesticides, herbicides, insecticides	Poor farming practices causing excessive erosion of sediment and chemicals from fields
	Temperature increase in body of water adjacent to agricultural fields	Shade trees and shrubs removed from stream bank for irrigation or agricultural expansion, exposing the water to direct sunlight
	Natural flow of water impeded	Dams, dikes, and diversions for agricultural practices decrease flow rate of water, absorbing more heat from sunlight
	Reduced ability to contain suspended solids, chemicals, and excess water from runoff	Draining swamps and marshes for farmland
Manure piles	Organic waste entering water from runoff	Improper containment of farm animal waste
Animal grazing	Organic waste entering water from runoff	Direct discharge from farm animals with access to waterways or waste entering a body of water as runoff
RESIDENTIAL		
Housing	Excess water and chemical runoff, runoff from fertilized and impervious land	Urbanization leads to increasing numbers of buildings, homes, and roads on lands that previously were natural areas, runoff from driveways and lawn
	Reduction in vegetation shading body of water	Shade trees and shrubs removed from watershed for housing development, exposing the water to direct sunlight and increasing sediment and suspended solids entering a body of water from erosion
Septic systems and gray water fields	Human wastes and/or gray water leaking into groundwater	Leaking or failing septic systems
	Detergents	Household cleaning agents washing into water and sewage systems
Dumping	Trash	Litter washed into sewer systems
	Organic waste—once part of a living plant or animal (food, leaves, feces, et.)	Pet wastes not collected and disposed of properly Grass, tree, and shrub clippings washed into sewer systems
SCHOOL	Runoff from fertilized and impervious land	Impervious land cover such as sidewalks, playgrounds and parking lots causes excessive runoff
	Trash	Litter washed into adjacent waterways or sewer systems

COMMERCIAL/INDUSTRIAL	Reduction in vegetation shading body of water	Shade trees and shrubs removed from watershed for commercial/industrial development, exposing the water to direct sunlight and increasing sediment and suspended solids entering a body of water
	Organic waste	Wastewater treatment plants Discharge from food-processing plants, meat-packing houses, dairies, and other industrial sources Organic waste from fibers originating from textile and plant processing plants
	Runoff from fertilized or impervious land	Impervious land cover such as parking lots and sidewalks causes excessive runoff
	Industry and power plant discharge	Industrial cooling process; water returned to source body of water is at higher temperature than at initial intake point Industrial or mining drainage
CONSTRUCTION , buildings and roadways	Sediment and suspended solids	Construction of new buildings, homes, and streets causes excessive erosion Paved roads cannot absorb chemicals, soil, and suspended particles in runoff Draining swamps and marshes for commercial or residential development reduces water catchment ability and filtering of silt and suspended solids Dredging waterways
	Temperature increase	Dams, dikes, and diversions for drinking water intake decreases flow rate of water, absorbing more heat from sunlight
PUBLIC USE		
Zoo	Organic waste	Direct discharge from mammals and birds as waste entering a body of water as runoff
Parks and golf courses	Runoff from fertilized and impervious land	Chemical runoff from golf courses and recreational parks entering a body of water as runoff Impervious land cover such as parking lots causes excessive runoff
Airports, bus stations, train stations	Runoff from impervious land	Impervious land cover such as parking lots causes excessive runoff
Marina or shipping port	Petroleum products	Chemical pollutants from point or nonpoint source pollution

Adapted from Earth Force GREEN Protecting Our Watersheds Poster **Land Use Conditions**

Physical Conditions

OBSERVATIONS	POSSIBLE ASSOCIATED PROBLEMS	POSSIBLE ASSOCIATED CAUSES
WATER APPEARANCE		
Green, Green-Blue, Brown or Red	Indicates the growth of algae	High levels of nutrient pollution, originating from organic wastes, fertilizers, or untreated sewage
Muddy, Cloudy	Indicates elevated levels of suspended sediments, giving the water a muddy or cloudy appearance	Erosion is the most common source of high levels of suspended solids in water. Land uses that cause soil erosion include mining, farming, construction, and unpaved roads.
Dark Reds, Purple, Blues, Blacks	May indicate organic dye pollution	Originating from clothing manufacturers or textile mills
Orange-Red	May indicate the presence of copper	Copper can be both a pollutant and naturally occurring. Unnatural occurrences can result from acid mine drainage or oil-well runoff.
Blue	May indicate the presence of copper, which can cause skin irritations and death of fish	Copper is sometimes used as a pesticide, in which case an acrid odor might also be present.
Foam	May indicate presence of soap or detergent	Excessive foam is usually the result of soap and detergent pollution. Moderate levels can also result from decaying algae, which indicates nutrient pollution.
Multi-Colored (oily sheen)	Indicates the presence of oil or gasoline floating on the surface of the water. Oil and gasoline can cause poisoning, internal burning of the gastrointestinal tract and stomach ulcers.	Oil and gasoline pollution can be caused by oil drilling and mining practices, leaks in fuel lines and underground storage tanks, automotive junk yards, nearby service stations, wastes from ships, or runoff from impervious roads and parking lot surfaces.
No Unusual Color	Not necessarily an indicator of clean water	Many pesticides, herbicides, chemicals, and other pollutants are colorless or produce no visible signs of contamination.
ODORS		
Sulfur (rotten eggs)	May indicate the presence of organic pollution	Possible domestic or industrial wastes
Musty	May indicate presence of organic pollution	Possible sewage discharge, livestock waste, decaying algae, or decomposition of other organic pollution
Harsh	May indicate presence of chemicals	Possible industrial or pesticide pollution
Chlorine	May indicate the presence of over-chlorinated effluent	Sewage treatment plant or a chemical industry
No Unusual Smell	Not necessarily an indicator of clean water	Many pesticides and herbicides from agricultural and forestry runoff are colorless and odorless, as are many chemicals discharged by industry.
EROSION	Sediment and suspended solids	Land uses that cause soil erosion include mining, farming, construction, unpaved roads, and deforestation.
DUMPING	Decomposition of organic material or human made products, presence of chemical or metal pollutants in water, presence of oil or gasoline in water	Construction, urbanization

DISCHARGE PIPES	Organic wastes, detergents, chemical/industrial runoff, sewage, temperature increase in body of water	Improper industrial waste treatment, improper sewage or gray water treatment
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Adapted from Earth Force GREEN Protecting Our Watersheds Poster **Physical Conditions**

Water Quality Conditions

CONDITIONS OBSERVED	POSSIBLE PROBLEMS	POSSIBLE CAUSES
Decrease in Dissolved Oxygen	Temperature Increase	Reduction in vegetation shading body of water; increase in sediment or suspended solids; industrial cooling processes
	Organic waste—once part of a living plant or animal (food, leaves, feces, etc.)	Leaking or failing septic systems; waste from farms and animals (pets and feedlots); discharge from food-processing plants, meat-packing houses, dairies, and other industrial sources; garbage; industrial waste (organic fibers from textile, paper, and plant processing); sewage treatment plants, natural processes; grass, tree, and shrub clippings; urban runoff; agricultural runoff
	Chemical runoff—herbicides, pesticides, insecticides	Golf courses; residential lawns; agricultural lands; recreational parks
	Trash	Litter washed into sewer systems
	Lack of algae and rooted aquatic plants	Multiple sources of water pollution (e.g., chemicals, toxins)
	Low water levels	Climatic or weather change Diversions for irrigation, hydroelectricity, drinking water, etc.
Fecal Coliform Bacteria <i>E. coli</i> enterococci	Organic waste—feces from human beings or other warm-blooded animals	Leaking or failing septic systems; failing sewer systems Direct discharge from mammals and birds with access to waterways or waste entering a body of water as runoff
Increase in Temperature (thermal pollution)	Organic waste—once part of a living plant or animal (food, leaves, feces, etc.)	Natural Processes; grass clippings; tree and shrub clippings; unnatural fish or animal kills
	Reduction in vegetation shading body of water	Shade trees and shrubs removed from stream bank for urban development, irrigation, and industrial and agricultural expansion, exposing the water to direct sunlight
	Industry and power plant discharge	Water returned to source is at higher temperature than at initial intake point
	Runoff from warmed urban surfaces	Impervious land cover such as paved streets, sidewalks, and parking lots Urbanization leading to increased numbers of buildings, homes, and roads on lands, that previously were natural areas and absorbed rain and snowmelt more efficiently
	Suspended solids	Removal of streamside vegetation; overgrazing; poor farming practices and construction causing excessive soil erosion
	Flow of water impeded	Dams, dikes, and diversions for agricultural, industrial, or municipal practices decrease flow rate of river, absorbing more heat from sunlight Dams created from beavers or log jams
Turbidity High total dissolved solids/total solids	Suspended solids (ranging from clay, silt, and plankton, to industrial wastes and sewage)	Erosion from agricultural fields; construction sites; residential driveways, roads, and lawns; natural and accelerated erosion of stream bank; excessive algae growth Leaves and plant materials Wastewater treatment plant Runoff from urban areas Dredging waterways Waste discharge (garbage, sewage) Excessive population of bottom-feeding fish (such as carp) that stir up bottom sediments

Excessive phosphates	Human wastes	Leaking or failing septic systems; sewage treatment plants
	Organic waste—once part of a living plant or animal (food, leaves, feces, etc.)	Waste containers leaking; lack of waste storage facilities; animals have direct access to waterways Pet wastes not collected and disposed of properly Removal of natural vegetation for farming or construction practices, causing soil erosion Draining swamps and marshes for farmland or commercial/residential development Drained wetlands no longer functioning as filters of silt and phosphorus
	Runoff from fertilized land	Agricultural fields; residential lawns; home gardens; golf courses; recreational parks
	Industrial waste	Poorly treated sewage; broken pipes; farms; golf courses; sewage treatment facilities; industrial discharges
	Detergents	Household and commercial cleaning agents washing into water and sewage systems
	Natural events	Forest fires and fallout from volcanic eruptions
Excessive nitrate	Runoff from fertilized land	Agricultural fields; residential lawns; golf courses; recreational parks
	Human wastes	Leaking or failing septic systems; sewage treatment facilities
	Animal wastes	Waste containers leaking; lack of waste storage facilities; animals (particularly ducks and geese) that have direct access to waterways Pet wastes not collected and disposed of appropriately
	Organic waste—once part of a living plant or animal	Natural processes; grass clippings; tree and shrub clippings; unnatural fish or animal kills
pH	Vehicles for transportation	Improper maintenance of vehicles
	Industrial waste	Industrial or mining drainage; sewage treatment plants
	Runoff from fertilized land	Agricultural fields; residential lawns; golf courses; recreational parks
pH & alkalinity	Acid rain (beginning in neighboring regions)	Excessive air pollution from burning fossil fuels for automobiles, boats, planes, etc.
Salinity	Salt and oil runoff	Paved roads cannot absorb substances, such as salts used on roads in winter; irrigation water picks up salts in soil
	Bodies of salt water mixing with fresh water	Water tables decrease in areas where water is being pumped (used) at levels exceeding replenishment capability
High conductivity	Discharges into the water	Failing sewage systems High temperature Water used for irrigation Discharge of heavy metals into the water
Low conductivity	Discharges into the water	Oil spill Low temperature

Adapted from Earth Force GREEN Protecting Our Watersheds Poster **Water Quality Conditions**

Chapter 8, Sustainable Fishing Practices

New Ideas

- **The Biological Basis for Fishing Regulations**
- **Catch and Release**

Introduction

Sustainability is a fashionable word in current conservation literature, but what exactly does it mean? One definition is, “using resources in such a manner that they will be available to future generations. For our purposes, it means managing fisheries so that they continue to be healthy, functioning ecosystems that support breeding stocks of catchable fish. Sustainable fishing practices have two components: (1) thoughtful regulations that are grounded in good science, and (2) angling practices that are ethical and in line with those regulations.

The Biological Basis for Fishing Regulations

Regulations may include bag or creel limits, slot limits, open and closed seasons, and restrictions on fishing techniques or tackle. Creel, size, and slot limits are all management tools. They allow anglers to harvest some fish while maintaining a healthy population. **Creel limits** are based on population ecology and aim to keep an adequate number of spawning-sized fish in a given body of water. Population ecologists use field data and mathematical models to decide what the appropriate creel and size limits are.

Size limits mandate that fish must be over some minimum length in order to be kept. The limit is chosen to guarantee that fish will get to reproduce before they are taken. These limits will vary, depending on the species of fish in question. For example, a female white sturgeon must be 15 or 20 years old and over 5 feet long before she reproduces. A bluegill sunfish, on the other hand, will reproduce at 2 years old. Both sturgeon and sunfish are popular angling targets. Which population is more likely to need the support of regulations to stay out (or get out) of trouble?

Slot limits protect fish within a certain “slot,” or size range. A slot limit of 14”-18” means that anglers may keep fish smaller than 14 inches or larger than 18 inches. Slot limits restrict the taking of fish to individuals smaller than reproductive age or trophy-sized. This serves two purposes: (1) fish are protected for their first few years of reproductive age and can spawn freely during those years, and (2) once fish reach reproductive age, they are more likely to be “promoted” to the next size class, which is the trophy class at the high end of the slot. A slot limit also has different effects on male and female fish of some species, like largemouth bass. One male can fertilize a number of females, so in order to maximize a population’s reproductive rate, there would ideally be many more males than females. When hunting for deer, people shoot males rather than females in order to keep the populations healthy. Male and female fish are much harder to distinguish than bucks and does, but since females grow much faster than males, a minimum size limit will usually result in the capture of many more females than males. Installing a slot limit instead of a minimum length limit will help ensure that more males than females are harvested, which will bolster the population and protect females while they grow to trophy size (Florida Fish & Wildlife Conservation Commission, 2001).

Catch and Release

Catch and release fishing is a creel limit of zero. Sometimes it is the law, in order to protect a population that is at risk of extinction. In other cases, it is practiced to protect a population that is healthy, but that experiences a great deal of fishing pressure. Some anglers, along with organizations like TU, choose to practice catch and release fishing voluntarily, whether or not it is required by law. Certain fishing practices can increase the likelihood that caught-and-released fish will survive. You should follow the same practices if you plan to keep just some of the fish you catch, since you will have to return part of your catch.

- Play and land fish quickly: do not use lighter tackle than a stream demands; that will extend time spent fighting and exhaust fish.
- Always wet hands before handling live fish. Dry hands can rub off mucus and scales, which makes fish more susceptible to fungal and bacterial infections.
- Do not dangle a fish in the air when you bring it in. Their internal organs are usually supported by the water's buoyant force, so when they are in the air or on land, their organs feel crushingly heavy. Try to minimize the trauma of being caught.
- Use barbless hooks or crush barbs using forceps. This will make releasing fish much quicker, and it is much safer for people in the boat or on the bank.
- If a fish is very deeply hooked, just cut the leader to release it. Jerking the hook around can cause a great deal of trauma, and trout often do just fine with small lures left in their mouths. The hook will work its way out.
- If a fish is played out, hold it facing upstream with one or two hands under its belly. Oxygenated water will flow through the gills and revive it.

By using these techniques, anglers can return healthy fish to the water, where they can thrive, reproduce, and be caught again. Some angling practices that are legal are not necessarily ethical. It is often perfectly legal to harvest fish while they are spawning, and some fish are more aggressive, and thus easier to catch, while they are spawning. Still, many anglers would agree that it's best to leave fish alone at this vital time in their life cycle.

Students who are backpack or are involved in other wilderness activities may have heard of Leave No Trace (LNT) wilderness ethics. Its principles are good guidelines for any angler, and they make sense from a health and safety perspective, as well as a conservation one. Examples of LNT practices:

1. Plan ahead and prepare
2. Dispose of waste properly: pack out what you pack in!
3. Leave what you find
4. Respect wildlife

One might not think of these practices as part of a particular wilderness philosophy, but most experienced outdoorspeople would mention all of them as ways to make an outdoor experience enjoyable and for future users. Learn more about Leave No Trace at <http://www.lnt.org/>.

References

Florida Fish and Wildlife Commission, 2001
 Leave No Trace, Inc., 2002

Chapter 9, Ethics & Etiquette

New Ideas

- **Fishing Ethics & Etiquette**

Introduction

This is another chapter whose lessons should be taught every day, but it's a good idea to take a lesson or two to talk specifically about fishing ethics and etiquette.

An ethic is a system of moral standards. Etiquette is the body of rules for behavior that are prescribed by an ethic. Etiquette might be different for two individuals in the same situation, e.g. the upstream and downstream fishermen. Still, they are following the same set of ethical principles. Most ethical systems end up prescribing similar behavior, like the golden rule of treating others as you would like them to treat you.

Fishing Ethics & Etiquette

Fishing ethics involve fulfilling an obligation to the fish, the environment, and your fellow users, both in the present and the future. Anglers should consider a number of different groups when they consider what is ethical: other anglers and angler associations, people who use the water for different recreational pursuits, the agencies that govern the resource, landowners, and the organisms that live in the water are all stakeholders in coldwater resources.

Fly fishing naturally breeds ethical behavior, as it demands respect for the fish we pursue. Preserving coldwater resources is the only way to ensure that the places where anglers fish will be around in the future, and creating respectful relationships with other anglers is the best way to create a unified group of anglers that can (go after) the conservation. Fishing etiquette is fairly commonsense to anyone who has spent some time fishing. Most of it simply involves treating the stream with respect, and treating other anglers as you would like them to treat you when you are fishing. A few guidelines for etiquette while fishing on any stream or lake are:

- Always obey posted regulations, and be familiar with state fish and game laws. Statewide regulations are all published in the booklet that comes with a new fishing license. It's good to get in the habit of looking regulations up before you go to a new stream.
- Report anglers who violate regulations.
- Approach the water quietly and cautiously. Try to avoid throwing a shadow over the water.
- Anglers fishing upstream have the right of way over anglers fishing downstream.
- If you come upon another angler on a stream, leave the water and walk around him well away from the bank. Re-enter the water sufficiently far away from him.
- Never float over the area where another angler is fishing. Stop your boat or float tube and wait.
- Never crowd other anglers.
- Obey posted "No Trespassing" and "No Fishing" signs on private property. Ask permission before you cut through private property to get to the water.

- Be a low-impact fisherman.
 - Don't litter, and pick up the litter that others have left behind.
 - Avoid causing extra erosion; don't cut trails or climb steep banks.
 - Don't throw rocks or wade noisily through weed or gravel beds where fish might be resting or spawning.
 - Wash your waders, boots, and equipment before you travel between streams to avoid spreading diseases and parasites.
- Do not fish for especially vulnerable fish, e.g. ones that are spawning or in very difficult conditions.
- Have fun! Enjoy the activity, the time with your fishing partners, and the outdoor experience, no matter what kind of luck you're having.

Have students think about how these practices: how do they follow from what students already know about fish biology and behavior?

- Do faucets and showers have aerators or low-flow showerheads?
- Does the toilet run for a long time after it is flushed?
- Is the garden getting more water than it needs? **Xeriscaping** the yard, installing drought-tolerant plants, is a big project, but it could be a fun one to involve the whole family.

49 different ways to save water, as individuals and as families, are at the American Water Savers website, <http://www.americanwater.com/49ways.htm>.

Conserving energy is an indirect way to protect coldwater resources. Hydropower-generation dams are a serious threat to trout and salmon, and coal and oil-burning power plants are major contributors to acid rain. Turn off the lights and the air conditioner when you leave the house, and in the winter, keep the thermostat set to 68°F instead of 72°F. Bike or walk, instead of driving, whenever you can, and share rides whenever it is possible. Brainstorm with students about more ways to conserve water and power. There are literally hundreds of such lists on the internet, and in conservation literature. To name a few:

- 40 ways to save energy, from the Los Angeles Department of Water and Power: <http://www.ladwp.com/resserv/coninfo/wayssave/40ways.htm>
- *50 Simple Things Kids Can Do to Save the Earth* (by Earth Works Group) is a book that lists 50 suggestions for ways to change consumer habits to save the environment. It also has some astounding facts about the quantity of water, matter, and power people waste.
- The New York City Department of Environmental protection has water-saving fact sheets and tips at <http://www.nyc.gov/html/dep/html/hcisw.html>. Some of the things you'll learn there are surprising, others are funny. For example, did you know that putting a tightly-capped plastic bottle full of water in your toilet tank will save water? A 1-quart bottle will save a quart per flush, a 2-liter bottle will save 2 liters, and so on.

Preventing pollution is a third class of everyday actions that kids can take to help trout and salmon. In fact, conserving water and power are two ways to prevent pollution: when one avoids over-watering lawns and gardens, one keeps lawn fertilizer and Roundup® from going down the storm drain. Reducing runoff, even unpolluted runoff, helps keep waterways clean, because it keeps flow closer to natural levels. That means that wetlands and marshes can do their job and filter water before it is returned to the aquifer. Families can also use fewer chemicals, and use those chemicals that they must use in a more responsible manner.

- Apply cleaning solutions only as directed. Dilute adequately, and do not use more than directed. Use alternative substances, like vinegar or "elbow grease," whenever possible.
- Dispose of waste properly. Take unwanted household chemicals to hazardous waste collection centers; don't pour them down the drain. Sending chemicals down the drain can keep septic systems from working properly or contaminate treatment plant sludge.

- Practice integrated pest management (IPM) in your yard. Choose plants that resist weeds and insects, and that don't need much water or fertilizer, to reduce inputs necessary to maintain it.
- Compost leaves and lawn clippings, or leave the clippings on the lawn. Use them as fertilizer, rather than adding them to a landfill.
- Help reduce river pollution by stenciling "Do Not Dump" near storm drains. To get information about stormwater pollution and directions for stenciling storm drains, go to <http://www.earthwater-stencils.com/>.
- These tips, and many more, are in the EPA article, "Do's and Don'ts Around the Home." <http://www.epa.gov/owow/nps/dosdont.html>
- A kids' page on preventing NPS pollution is <http://www.epa.gov/owow/nps/kids/>

What Trout Unlimited Does

Trout Unlimited is a national organization of fly fishermen whose mission is "to conserve, protect and restore North America's coldwater fisheries and their watersheds." TU is a national organization, with 130,000 members in 450 chapters in 36 states. The heart of TU's operations is local chapters. Local chapters, like the one running this program (insert appropriate plug here), get anglers together to fish and take care of their home rivers. Local chapters do restoration projects, education, and advocacy work.

One of the most popular projects for local TU chapters, and one that kids can easily get involved in, is habitat restoration. Habitat restoration usually involves replanting riparian vegetation and adding features to stream habitat that will help trout. For example, kids at the Cumberland Valley Chapter's Rivers Conservation & Fly Fishing Youth Camp have been improving habitat on the Yellow Breeches River for 8 years (as of August 2002).

TU National supports and coordinates local efforts. It also takes on national issues, like environmental or energy bills in Congress. It has people raising money; lobbying for laws that will protect, rather than hurt, trout; publishing information about coldwater fisheries conservation; coordinating volunteers; and helping local chapters find the information and resources that they need. TU National also supports scientific research to figure out how best to protect, manage, and restore fisheries and watersheds. For example, it helped fund a study carried out by University of Alaska's (Anchorage) Environment and Natural Resources Institute that investigated the effects of salmon ranching on wild Pacific salmon populations.

To find out about TU's current campaigns, check the website, <http://www.tu.org/>, or get a copy of the annual report by emailing trout@tu.org or calling (703) 284-9410.

Resources for Conservation and Advocacy Projects

As described above, your local TU chapter is often the best place to start a conservation or advocacy project. The organization has several ongoing grassroots campaigns designed to mobilize volunteers for fisheries conservation projects. The local chapter may already be participating in one, or you might want to find out how you could help get your chapter involved.

- [Home Rivers](#) (watershed restoration)
- [Embrace-A-Stream](#) (fishery resource, research and education)
- [Shared Streams](#) (streams on private forest lands)

- Bring Back the Natives (native species on federal lands)
- TU/Forest Service Partnership (fish recovery in National Forests)

One type of project that student groups can undertake is a water monitoring projects. Monitoring streams involves periodic testing and surveying to determine water quality, detect changes, and find out when water quality is being compromised. They are also a fun, active way to teach science skills. A number of groups have resource guides or web pages devoted to water monitoring for kids.

- The EPA has an extensive Water Quality Monitoring program, including a volunteer monitoring center. Their home page also links to a database that lists existing monitoring programs that a group might “plug into” from all over the country. <http://www.epa.gov/owow/monitoring/>
- The Izaak Walton League Save Our Streams Program has monitoring and action programs nationwide. Their website is <http://www.iwla.org/sos/>; click on the “publications” button, and then “tools,” to find monitoring information and equipment.

An advocate is a supporter or defender of a cause. Being advocates for trout and salmon is a big part of TU’s mission. Once students have identified the policies and practices that are causing the watershed problem they are concerned with, they may feel that they need to speak out to try and change the practices of people or businesses in the community, or even local ordinances or laws. Such a project is likely to be a major commitment, but it will be rewarding.

- Trout Unlimited published *Speaking for Trout and Salmon: the TU Member’s Guide to Environmental Law and Advocacy*. Groups can download it off the TU website library, or they can call (703) 284-9420 or email trout@tu.org to request a copy.
- Earth Force GREEN’s Protecting Our Watersheds (POW) program is designed to help middle schoolers study watersheds and work on projects to improve their health. The POW activity book gives teachers or leaders the resources to mentor student groups through the entire advocacy process. It breaks a long, complicated process down into manageable steps, all the way from performing field research to assess water quality to taking civic action. The teacher guide and activity book, in addition to water quality monitoring materials, can be ordered from the website, at <http://www.green.org/>, or by calling them at (703) 299-9400.

Chapter 10, What You Can Do

New Ideas

- **Everyday Conservation Actions**
- **What Trout Unlimited Does**
- **Resources for Conservation and Advocacy Projects**

Activities

Activity #16: Taking Account of Water, p. 101

- o **Handout: My Daily Water Use, p. 103**

Activity #17: What's Causing What's Wrong?, p. 105

Introduction

Environmental publications often contain lists of dire predictions: how many undiscovered rainforest organisms die each week, how fast the world is running out of clean drinking water, and other threats to the planet. Although they can be depressing, such figures can serve as a call to action. Rather than dwelling on them, we can learn from previous successes and focus on ways to help. This section outlines environmental actions that kids can take, from daily practices they can adopt, to resources for taking on a local restoration project or working as advocates. It also explains what TU does, and how it the organization can help them make a difference in trout and salmon conservation.

Everyday Conservation Actions

Now that students have some knowledge of trout biology and the problems that threaten coldwater resources, they can start taking action to protect them. Making conscientious decisions in one's everyday life, and encouraging friends and family to do the same, is easy the first, easiest way to help. Conserving water, conserving energy, and reducing pollution are the best ways to do it.

Conserving water is the first thing to think about. Ask students to think about what they did before arriving here this morning. How could they conserve water at every step? **Activity #16, Taking Account of Water, p. 101**, helps students calculate the amount of water you they each day. Encourage students to go over their results with their families and see what practices they could change together. On his or her own, any student can:

- take shorter showers
- avoid letting the water run in the bathroom or kitchen
- only run full loads of laundry or dishes
- be careful doing outdoor chores: don't overwater lawns and gardens, and don't let the water run on the sidewalk or street

Students can do "water conservation inventories" with their families. Look at practices like the ones outlined above, but also try to find appliances or fixtures that could be modified to work more efficiently.

- Do faucets and showers have aerators or low-flow showerheads?
- Does the toilet run for a long time after it is flushed?
- Is the garden getting more water than it needs? **Xeriscaping** the yard, installing drought-tolerant plants, is a big project, but it could be a fun one to involve the whole family.

49 different ways to save water, as individuals and as families, are at the American Water Savers website, <http://www.americanwater.com/49ways.htm>.

Conserving energy is an indirect way to protect coldwater resources. Hydropower-generation dams are a serious threat to trout and salmon, and coal and oil-burning power plants are major contributors to acid rain. Turn off the lights and the air conditioner when you leave the house, and in the winter, keep the thermostat set to 68°F instead of 72°F. Bike or walk, instead of driving, whenever you can, and share rides whenever it is possible. Brainstorm with students about more ways to conserve water and power. There are literally hundreds of such lists on the internet, and in conservation literature. To name a few:

- 40 ways to save energy, from the Los Angeles Department of Water and Power: <http://www.ladwp.com/resserv/coninfo/wayssave/40ways.htm>
- *50 Simple Things Kids Can Do to Save the Earth* (by Earth Works Group) is a book that lists 50 suggestions for ways to change consumer habits to save the environment. It also has some astounding facts about the quantity of water, matter, and power people waste.
- The New York City Department of Environmental protection has water-saving fact sheets and tips at <http://www.nyc.gov/html/dep/html/hcisw.html>. Some of the things you'll learn there are surprising, others are funny. For example, did you know that putting a tightly-capped plastic bottle full of water in your toilet tank will save water? A 1-quart bottle will save a quart per flush, a 2-liter bottle will save 2 liters, and so on.

Preventing pollution is a third class of everyday actions that kids can take to help trout and salmon. In fact, conserving water and power are two ways to prevent pollution: when one avoids over-watering lawns and gardens, one keeps lawn fertilizer and Roundup® from going down the storm drain. Reducing runoff, even unpolluted runoff, helps keep waterways clean, because it keeps flow closer to natural levels. That means that wetlands and marshes can do their job and filter water before it is returned to the aquifer. Families can also use fewer chemicals, and use those chemicals that they must use in a more responsible manner.

- Apply cleaning solutions only as directed. Dilute adequately, and do not use more than directed. Use alternative substances, like vinegar or "elbow grease," whenever possible.
- Dispose of waste properly. Take unwanted household chemicals to hazardous waste collection centers; don't pour them down the drain. Sending chemicals down the drain can keep septic systems from working properly or contaminate treatment plant sludge.

- Practice integrated pest management (IPM) in your yard. Choose plants that resist weeds and insects, and that don't need much water or fertilizer, to reduce inputs necessary to maintain it.
- Compost leaves and lawn clippings, or leave the clippings on the lawn. Use them as fertilizer, rather than adding them to a landfill.
- Help reduce river pollution by stenciling "Do Not Dump" near storm drains. To get information about stormwater pollution and directions for stenciling storm drains, go to <http://www.earthwater-stencils.com/>.
- These tips, and many more, are in the EPA article, "Do's and Don'ts Around the Home." <http://www.epa.gov/owow/nps/dosdont.html>
- A kids' page on preventing NPS pollution is <http://www.epa.gov/owow/nps/kids/>

What Trout Unlimited Does

Trout Unlimited is a national organization of fly fishermen whose mission is "to conserve, protect and restore North America's coldwater fisheries and their watersheds." TU is a national organization, with 130,000 members in 450 chapters in 36 states. The heart of TU's operations is local chapters. Local chapters, like the one running this program (insert appropriate plug here), get anglers together to fish and take care of their home rivers. Local chapters do restoration projects, education, and advocacy work.

One of the most popular projects for local TU chapters, and one that kids can easily get involved in, is habitat restoration. Habitat restoration usually involves replanting riparian vegetation and adding features to stream habitat that will help trout. For example, kids at the Cumberland Valley Chapter's Rivers Conservation & Fly Fishing Youth Camp have been improving habitat on the Yellow Breeches River for 8 years (as of August 2002).

TU National supports and coordinates local efforts. It also takes on national issues, like environmental or energy bills in Congress. It has people raising money; lobbying for laws that will protect, rather than hurt, trout; publishing information about coldwater fisheries conservation; coordinating volunteers; and helping local chapters find the information and resources that they need. TU National also supports scientific research to figure out how best to protect, manage, and restore fisheries and watersheds. For example, it helped fund a study carried out by University of Alaska's (Anchorage) Environment and Natural Resources Institute that investigated the effects of salmon ranching on wild Pacific salmon populations.

To find out about TU's current campaigns, check the website, <http://www.tu.org/>, or get a copy of the annual report by emailing trout@tu.org or calling (703) 284-9410.

Resources for Conservation and Advocacy Projects

As described above, your local TU chapter is often the best place to start a conservation or advocacy project. The organization has several ongoing grassroots campaigns designed to mobilize volunteers for fisheries conservation projects. The local chapter may already be participating in one, or you might want to find out how you could help get your chapter involved.

- [Home Rivers](#) (watershed restoration)
- [Embrace-A-Stream](#) (fishery resource, research and education)
- [Shared Streams](#) (streams on private forest lands)

- Bring Back the Natives (native species on federal lands)
- TU/Forest Service Partnership (fish recovery in National Forests)

One type of project that student groups can undertake is a water monitoring projects. Monitoring streams involves periodic testing and surveying to determine water quality, detect changes, and find out when water quality is being compromised. They are also a fun, active way to teach science skills. A number of groups have resource guides or web pages devoted to water monitoring for kids.

- The EPA has an extensive Water Quality Monitoring program, including a volunteer monitoring center. Their home page also links to a database that lists existing monitoring programs that a group might “plug into” from all over the country. <http://www.epa.gov/owow/monitoring/>
- The Izaak Walton League Save Our Streams Program has monitoring and action programs nationwide. Their website is <http://www.iwla.org/sos/>; click on the “publications” button, and then “tools,” to find monitoring information and equipment.

An advocate is a supporter or defender of a cause. Being advocates for trout and salmon is a big part of TU’s mission. Once students have identified the policies and practices that are causing the watershed problem they are concerned with, they may feel that they need to speak out to try and change the practices of people or businesses in the community, or even local ordinances or laws. Such a project is likely to be a major commitment, but it will be rewarding.

- Trout Unlimited published *Speaking for Trout and Salmon: the TU Member’s Guide to Environmental Law and Advocacy*. Groups can download it off the TU website library, or they can call (703) 284-9420 or email trout@tu.org to request a copy.
- Earth Force GREEN’s Protecting Our Watersheds (POW) program is designed to help middle schoolers study watersheds and work on projects to improve their health. The POW activity book gives teachers or leaders the resources to mentor student groups through the entire advocacy process. It breaks a long, complicated process down into manageable steps, all the way from performing field research to assess water quality to taking civic action. The teacher guide and activity book, in addition to water quality monitoring materials, can be ordered from the website, at <http://www.green.org/>, or by calling them at (703) 299-9400.

Activity #16: Taking Account of Water

Introduction

Students will be asked to record their water usage over the course of 24 hours. You may want to ask them to record usage over a weekend and then average the numbers they get over 24 hours, since people tend to do things like laundry, washing cars, and gardening on the weekend.

Time: 40 minutes on each of 2 consecutive days

Ages: grades 5-8

Materials

- One copy of **My Daily Water Use** worksheet (p. 103) and a pen or pencil per student

Prep Work: gather materials

Procedure

1. Ask students how many gallons of water they think they use per day. Give each student a **My Daily Water Use** worksheet. Have them record their estimates in the “Estimated Daily Use” box on the table.
2. Tell students that over the next 24 hours, they should put a mark in the “Times per Day” column each time they use water.
3. The next day, after students have completed the worksheets, read the quantities listed below and have students fill them in on the “Gallons per Activity” column of the worksheet. (Numbers are estimates.)

Washing hands	.25 gal
Brushing teeth	1 gal
Flushing toilet	5 gal.
Laundry	30 gal./load
Shower	30 gal.
Bath	40 gal.
Hand washing car	8-10 gal./min.
Commercial car wash	12 gal. (total)
Hand washing dishes	10 gal.
Machine washing dishes	15 gal.
Watering lawn	8-10 gal./min.

4. Tell students to multiply the gallons per activity by the number of times they did each activity in a day to fill in the “Daily Use” column. Total the numbers in the “Daily Use” column to fill in the “Total Daily Use” box.

Discussion

- Ask students what their daily use totals were. Tell them that the average U.S. resident uses about 100 gallons per day. The average person in the developing world uses about 13 gallons. Ask students to explain the discrepancy.
- Which of their activities used the most water?
- Do some quick calculations: how much water would you save by taking a shower instead of a bath? By washing the car at a car wash instead of at home?
- Discuss simple ways to save water. How can we encourage others to do the same?

Adapted from “Taking Account of Water,” National Geographic Society, 2001

My daily water use			
Estimated Daily Use			
Activity	Times per day	Gallons per activity	Daily use
Washing hands			
Brushing teeth			
Flushing toilet			
Laundry			
Shower			
Bath			
Washing car			
Hand washing dishes			
Machine washing dishes			
Watering lawn			
Add 1 gallon for food preparation and drinking through the day			
Total daily use			

Activity #17: What's Causing What's Wrong?

Introduction

Once students have identified a watershed problem or threat, this activity guides them through research using mass media. The aim of this research is to discover information about policies and practices that contribute to the problem.

Time: at least 1 hour

Ages: high school and older

Materials Recent articles from various sources about the problem the group is investigating.

- Pencils and paper
- Chart paper and markers

Prep Work: instructor must secure access to a library or media center with access to the internet and print periodicals. Students should also have a well-developed idea of what is wrong—e.g., what is the problem, what pollutants are causing it, what is/are the pollution source(s), and who is being affected?

Procedure

1. Explain to students that the purpose of their research is to investigate practices and policies as they relate to the environmental problem they are working on
2. Divide students into at least four groups: two at computers and two with newspapers and periodicals. For each media source, one group should look at policies, and the other at practices. Have each group choose a speaker and a scribe; ask each group to identify and list on chart paper the practices and policies they discover.
3. Ask each group to report how the problem or threat is related to policy and practice and who the players are.
4. Reconvene as a whole group. Ask probing questions such as, “Is the root problem a lack of policy, conflicting policies, poor enforcement, an uninformed public, or an uncaring public?” Discuss and mark on the chart paper which policies or practices they feel should be changed in order to solve the problem over the long term.

Discussion

Ask students to describe their own behaviors concerning the watershed, whether helpful or harmful. Ask why they do the helpful behaviors and what it would take for them to change the harmful ones.

Extensions

Research usually uncovers new questions about a problem, or even spurs investigators to redefine their questions. This trip may lead to a return visit, or students may decide to investigate government documents or other publications. One place to start is the GREEN (Global Rivers Environmental Education Network) website, <http://www.green.org/>.

Adapted from Earth Force GREEN *Protecting our Watersheds Activity Book*, Activity #13, “What’s Causing What’s Wrong?”

Sample Class Schedules

Each chapter and activity in this curriculum is designed to be able to stand on its own. Lectures and activities can be combined as you desire to suit your program's demands: the age of the students, the amount of time at hand, and the number of chapter members assisting will all help determine the unique shape of your program. Here are two examples of day-long schedules suitable for students of any age and a week of half-day classes for grade-school students.

Full-Day Class: Conservation

This field class could stand on its own as a one-day workshop for your local TU chapter, or it could be part of the program of another camp or recreational program.

8:00-9:00am: Instructors prepare site
 9:00-9:45am: Registration
 9:45-10:00am: Introductory lecture
 10:00-10:30am: Travel to stream
 10:30am-12:00pm: Activity #8, Stream Safari
 12:00-1:00pm: Sack lunch and discussion
 1:00-2:00pm: Guest Lecture from Department of Fish & Wildlife
 2:00-4:00pm: Stream restoration project
 4:00-5:00pm: Clean-up and transportation home

Full-Day Class, Fishing and Conservation

7:00-8:00am: Instructors prepare site
 8:00-8:45am: Registration
 8:45-9:00am: Introductory Lecture
 9:00-10:00am: Casting Practic
 10:00-11:00am: Fly Tying
 11:00am-12:00pm: Stream Life lecture
 12:00-1:00pm: Lunch
 1:00-2:00pm: Human Impacts lecture, concentrating on 1 or 2 local issues
 2:00-3:00pm: Water Quality Bioassessment and discussion
 3:00-5:00pm: Restoration project
 5:00-6:00pm: Dinner
 6:00-8:00pm: Fish evening hatch

Week-long, Half-Day Camp for 4th-6th Grade Students

Monday

- 8:00-8:30am: Camper drop-off and overview of rules and procedures with parents and campers
- 8:30-9:30am: Casting practice
- 9:30-10:30am: Ecological Concepts lecture, Activity #2, Connect the Critters
- 10:30-11:30am: Fly Tying
- 11:30am-12:00pm: Begin Activity #16, Taking Account of Water

Tuesday

- 8:00-8:30am: Casting Practice
- 8:30-9:30am: Knot tying
- 9:30-10:15am: Finish Activity #16, Taking Account of Water, and discuss.
- 10:15-11:00 Fly Tying
- 10:30-12:00: Stream Life lecture, Activity #7, Insect Life Stages Fill-In

Wednesday

- 8:00-8:30am: Receive campers and travel to stream
- 8:30-9:00am: Wader Safety lecture
- 9:00-10:00am: Activity #8 and #9, Stream Safari and Water Quality Bioassessment
- 10:00-10:30am: Reading the Stream
- 10:30am-12:00pm: Fishing

Thursday

- 8:00-8:30am: Discuss Reading the Stream (think about yesterday's fishing)
- 8:30-9:15am: Trout Behavior and Biology, Activity #10, Trout Fill-In
- 9:15-10:00am: Guest Lecture from local TU officer, discuss fishing and conservation projects
- 10:00-11:00am: Fly Tying with guest lecturer
- 11:00am-12:00pm: Human Impacts, discuss local issues

Friday

- 8:00-8:30am: Receive campers and travel to stream
- 8:30-10:30am: Help local TU members plant riparian vegetation
- 10:30am-12:00pm: Fish

Glossary

Acid rain Rainwater with an abnormally low pH, generally from industrial pollution.

Acidification The process by which a lake's pH becomes increasingly acid, until it can no longer support its natural ecological community.

Adaptation The ability to adjust to circumstances.

Alevin Larval fish. Not quite free-living, these feed on their attached yolk sacs.

Amplitude The height of a sound wave, corresponds to loudness.

Anadromous Sea-run, having a life cycle where trout born in fresh water spend a growth period in the ocean and then return to fresh water to spawn.

Anaerobic Without oxygen.

Annelid Advanced, segmented worms.

Aquatic Inhabiting a freshwater environment.

Aquifer An underground layer of porous rock, sand, or gravel containing water.

Arthropod Organisms from the phylum Arthropoda, which have hardened exoskeletons and segmented appendages, means "joint foot."

Benthic Living in or on the bottom of a sea or lake.

Best management practice (BMP) A practice used to reduce impacts from a particular land use.

Biomagnification The increased accumulation of toxic substances in the tissue of animals at higher levels of the food chain.

Catch and release Releasing, live, all the fish one catches.

Channel A conduit formed by the flow of water and debris.

Channelization The practice of straightening a waterway to remove meanders and make water flow faster. Sometimes concrete is used to line the sides and bottom of the channel.

Cloud A mass of condensed water droplets or ice crystals in the sky.

Competition When a number of organisms of the same or different species utilize common resources that are in short supply, or when organisms seeking the same resource interfere with one another.

Condense To change a gas into a liquid.

Consumer An organism that consumes (eats) other living things

Creel limit Regulation setting a maximum number of fish that an angler may keep.

Crustacean An animal that is a member of the class of arthropods that includes scuds and crayfish.

Current seam An area where slow and fast water meet.

Detrivore An animal that eats waste or dead matter from organisms at all trophic levels.

Dissolved oxygen (DO) Gaseous oxygen dissolved in aqueous water.

Ecological niche Role of an organism in its environment and its interactions with other organisms or species.

Ecology The branch of biology clearly with interactions between living organisms with each other and their environment.

Economy of effort The principle stating that animals will expend as little effort as possible when foraging so that their net energy gain is maximized.

Ecosystem A biotic (living) community and its abiotic (non-living) environment.

Energy The ability to do work.

Energy Pyramid A way of conceptualizing an ecosystem that illustrates energy loss at each trophic level.

Erosion Wearing away, specifically, the process by which flowing water wears away land.

Eutrophication Nutrient pollution, the process by which plant nutrients cause algal blooms and subsequent oxygen depletion.

Evaporation The process by which liquids turn into gas.

Evapotranspiration The combined conversion of water to water vapor and loss resulting from both evaporation and transpiration.

Food Chain A way of conceptualizing an ecosystem that emphasizes dependence for food of organisms upon others in a series beginning with plants and ending with top predators.

Food Web A way of conceptualizing an ecosystem that emphasizes numerous connections and interdependence

Friction The resistance to motion of surfaces that touch.

Fry A free-living larval trout.

Generalist An organism that feeds on numerous different sources.

Gill The breathing organ trout use to exchange oxygen from water with carbon dioxide from their blood.

Groundwater Recharge The process by which surface water percolates through the ground until it reaches the saturated zone and replenishes the groundwater supply.

Habitat The region where a plant or animal normally lives.

Hydrological cycle A model for understanding the movement of water through the hydrosphere.

Hydrology The study of Earth's waters, their distribution, and the cycle involving evaporation, precipitation, etc.

Hydrosphere All the water on and around the surface of the earth.

Indicator species A species so highly adapted to a particular environment that its presence is sufficient to indicate that specific conditions are met.

Instar A stage of development in an insect that undergoes during metamorphosis.

Interspecific competition Competition between members of different species.

Intraspecific competition Competition between members of the same species.

Invertebrate An animal without a backbone.

Keystone Species A predator whose ecological role maintains the diversity of the rest of the ecosystem, e.g., by controlling the population of another predator.

Kype The hooked lower jaw of a spawning male trout.

Lie The position, or territory, where a trout holds while it feeds.

Metamorphosis The physical change undergone by some animals as they grow from egg to adult.

Milt The milky fluid produced by male trout that contains sperm.

Mollusk An animal from the phylum Mollusca. Many, like clams and snails, are distinguished by their hard shells.

Nematode A roundworm from the numerous phylum Nematoda.

Niche See **Ecological Niche**.

Non-Point Source Pollution Pollution resulting from land use practices, rather than a single, identifiable source.

Nutrient A substance that gives energy and encourages growth.

Organism Any living thing.

pH A measure of the acid or basic character of a substance. The pH scale is a measure of the concentration of hydrogen (H⁺) ions in the substance.

Photosynthesis The process by which green plants convert the sun's energy into chemical energy in the form of carbohydrate.

Point Source Pollution Pollution from a single, identifiable source.

Pollution Contamination of the air, water, or soil.

Pollution Tolerance An organism's ability to withstand the effects of pollution.

Pool In streams, a relatively deep area with low velocity.

Population A potentially interbreeding individuals of a certain species living within a defined geographical area.

Precipitation Rain, snow, etc.

Predator An animal that kills and eats other animals (a scavenger would eat dead ones).

Prey An animal that is eaten by others.

Producer The first trophic level in a food web. Usually plants that convert the sun's energy into chemical energy that consumers can access by eating the producers.

Recharge See **Groundwater Recharge**.

Respiration "Breathing," or taking in oxygen and giving off carbon dioxide.

Riffle A shallow section in a stream where water is breaking over rocks or other partially submerged organic debris and producing surface agitation.

Riparian Of or pertaining to the banks of a river or stream.

Roundworm See **Nematode**.

Saltwater incursion When saltwater percolates into freshwater wells.

Sediment Solid matter that settles to the bottom of water.

Siltation The deposition of sediments on the upstream side of a dam.

Slot limit A fishing regulation that limits the taking of fish within a "slot" defined by lower and upper length limits.

Smolt A juvenile salmon one or more years old that has undergone physiological plans in preparation for migration to its marine habitat.

Solubility The ability of a chemical (e.g., pollutant) to be dissolved into a solvent (e.g., water column).

Spawning Mating.

Specialist An organism that consumes only one type of food or prey.

Stream meander The length of a stream channel from an upstream point to a downstream point divided by the straight line distance between the same two points.

Sustainability Using a resource in such a manner that it is available for future generations.

Synergy Combined effects greater than the additive sum of those effects.

Territorial Defending a region of habitat from intruders

Total Maximum Daily Load (TMDL) An estimate of the pollutant concentrations resulting from the pollutant loadings from all sources to a water body. The TMDL is used to determine the allowable loads and provides the basis for establishing or modifying controls on pollutant sources.

Transpiration The process by which plants give off water through their leaves.

Trophic Level An organism's place in the energy pyramid. Producers are the first trophic level, primary consumers are the second, secondary consumers are the third, and so on.

Turbidity Cloudiness, especially from stirred-up sediments.

Turbulence Agitation.

Undercut A place where water on the outside of a curve has cut a hollow under the stream bank.

Vertebrate An animal with a backbone.

Water Cycle See **Hydrological Cycle**

Water Mining Using the water in an aquifer at a faster rate than that at which the aquifer is recharged.

Water Vapor Water in its gaseous state.

Watershed A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river or lake at a lower elevation.

Width/depth ratio The width to depth ratio describes a dimension of bankfull channel width to bankfull mean depth. Bankfull discharge is defined as the momentary maximum peak flow, which occurs several days a year and is related to the concept of channel forming flow.

Xeriscape Landscaping with drought-tolerant plants in order to conserve water.

Zooplankton The animal portion of the plankton, i.e. the microscopic animal community that floats free in the water.

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