

Aquatic organisms

9

"Is ditch water dull? Naturalists with microscopes have told me that it teems with quiet fun."

— G.K. Chesterton

A healthy stream is a highly diversified ecosystem. Its complex food chain ranges from microscopic diatoms and algae to large fish, birds and mammals. The diversity of species, particularly aquatic organisms, and their numbers are important to any stream study for two reasons:

- as indicators of water quality in the stream and
- as parts of various food chains, including fish.

A wide variety of organisms inhabit water. The size and diversity of a population depend on

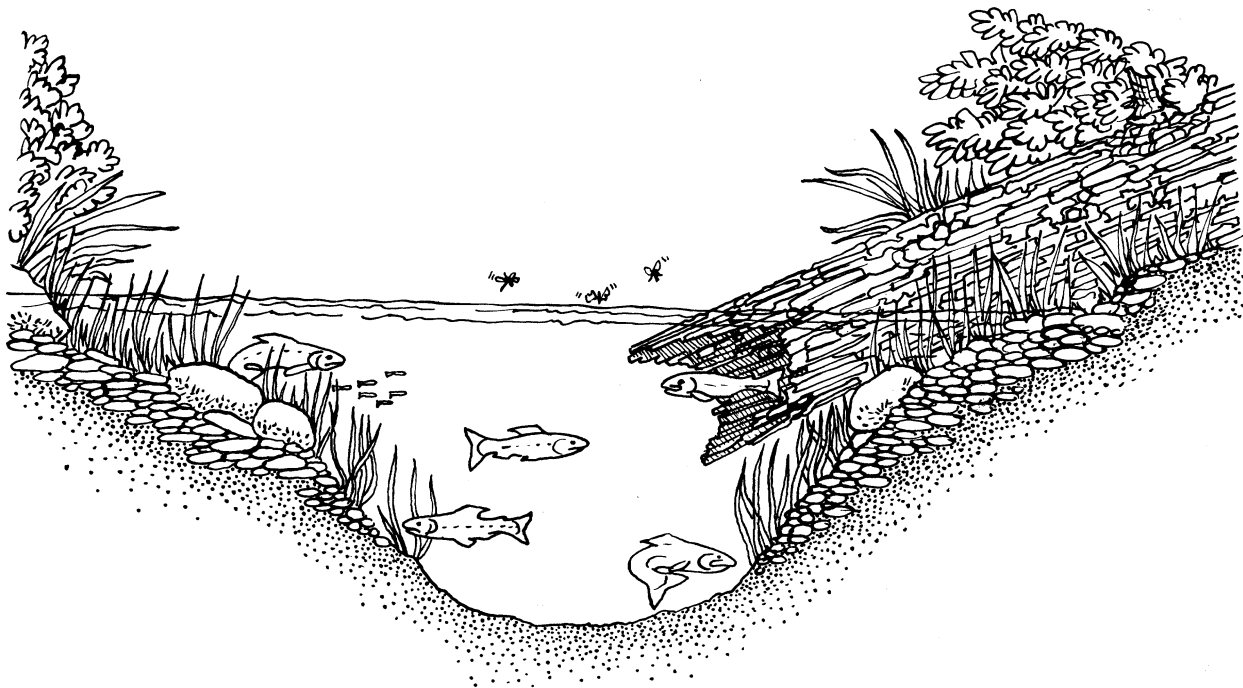
the quality of available water. Fish occupy an important position in the aquatic food chain and obtain their food supply from several sources.

The amount of food available in a stream is determined by the physical and biological conditions of the area. When producers are plentiful, consumers also flourish. Diatoms coating a rock feed primary consumers such as mayflies. They, in turn, feed higher-order consumers like stoneflies and fish.

Overhanging vegetation supplies a variety of terrestrial insects to the menu.

Vocabulary

benthic
hyporheic
plankton



Many aquatic insects use streamside vegetation during emergence and adult stages of their life cycle.

Some aquatic insects leave their positions among boulders and gravel in riffles and are carried downstream short distances before reattaching to the stream bottom. When insects are moving in a water column, as drift or during emergence, they are most vulnerable to being eaten.

Benthic (bottom dwelling) organisms are found on stones or in mud or vegetation. Because a streambed serves as a place for attachment, most organisms in a fast-moving stream will be benthic.

Organisms in fast water have many specialized methods for obtaining food. To gather food in a water column, they grasp it quickly or filter it from the water while remaining stationary. Others gather food on the bottom.

Plankton can be producers or consumers and float or swim freely throughout a stream. Few organisms can live in rapid sections of streams without being swept downstream by the current. Consequently, plankton are abundant in slower waters of large streams and rivers.

Stream ecologists have found a complex community of small animals living in the ground water below the stream channel and sometimes for miles on each side. Many types of small blind shrimp, primitive worms, bacteria, algae, and various kinds of immature insects live most, if not all, of their lives in a maze of channels in this

underground and under-river ecosystem. These organisms contribute to the health and productivity of the river by supporting the aquatic food chain that extends to and beyond the water's surface.

*The diversity of species,
particularly aquatic organisms
and their numbers, are
important to any stream.*

Evidence suggests that **hyporheic** (from Greek for "below" and "flow") exchange is significant in large streams, like the Santiam River of Oregon's Willamette Valley. Some scientists feel the stability of many streams may depend largely on these hyporheic zones, which exchange water and materials with the river channel. The hyporheic zone may extend 15 feet to 30 feet below the river bottom and two miles to either side of the river.

The knowledge of hyporheic zones, and the organisms found there, challenges traditional views of how rivers work. It may have an effect on river system assessments. It could also mean that measures to protect streams from pollution or alteration may need expansion to include wider areas along the watercourses.

Food processing

9.1

“And in the water winding weeds move round.”
—Wallace Stevens

In autumn, forest floors are piled high with leaves. But in spring, the Earth’s load is lightened; the leafy carpet has worn thin and seems to disappear with the melting snow. Where have the leaves gone? Those that stay where they fall are decomposed, for the most part, by soil invertebrates and microbes. But many of the “disappearing leaves” are carried down hill slopes into small, heavily canopied forest streams.

Most leaves and other organic materials blown by the wind, washed from the surrounding landscape, or fallen directly from overhanging limbs into watercourses do not get very far. They are trapped by rocks, logs and branches close to where they entered the water. They become part of the food or energy base of the stream.

Some of this material settles out in pools and backwaters. Leaves that get buried will decompose anaerobically. Because **anaerobic** processes are much slower than **aerobic** ones, buried leaves remain intact longer. These leaves can be recognized by their black color. Eventually the buried leaves are re-exposed, and decomposition continues aerobically, much as if they had never been buried.

This section is adapted from “Turning Over a Wet Leaf,” by Rosanna Mattingly, and used with permission from *The Science Teacher*, September 1985.

Functional feeding groups

What or who is responsible for all this aerobic decomposition? Leaf litter can be broken down and decomposed slowly by abrasion and microbial action, but streams also harbor invertebrates

*What is important is
not so much what,
but how the animals eat.*

that help decompose leaves and other organic materials under a variety of conditions. A rich, diverse population of aquatic insects is keyed to the varied quality of this food base.

Although most of us have seen our share of crayfish and snails, other aquatic invertebrates, a bit smaller and often a bit quicker, can easily elude us. The aquatic invertebrates we are interested in here are inconspicuous aquatic insect larvae and nymphs (immature forms). It is hard to distinguish one species from another at this

Vocabulary

aerobic	gatherers
anaerobic	predators
collectors	scrapers
filters	shredders

immature stage, and the nymphs' names are based, in general, on their adult characteristics. So, rather than identify these animals individually, we can group them according to the mode of feeding for which each animal is adapted. What is important is not so much what, but how the animals eat, hence the distinct functional feeding groups.

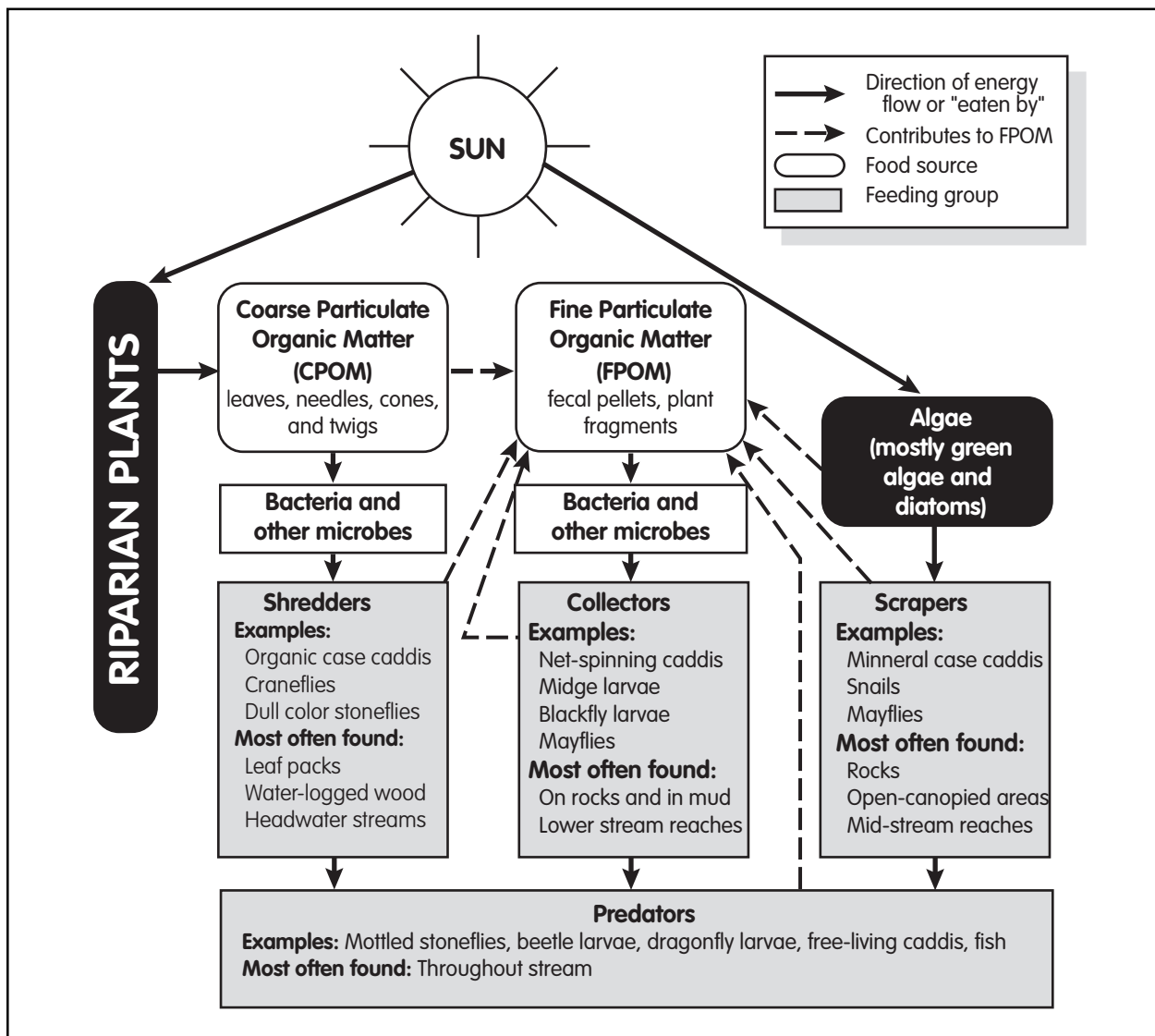
Shredders

Some aquatic invertebrates feed on leaves or other organic material—such as wood, needles

and fruits—by biting into them or by cutting or boring through them. These insects are called **shredders**. Shredders generally reduce whole leaves to masses of small particles, but they often leave the midrib and veins intact. Thus, they “skeletonize” the leaves. Many shredders prefer leaves that have been partially decomposed by microbes; with microbial decomposition, leaves become tender and digestible.

In the Pacific Northwest, litter from many soft-leaved shrubs is quickly colonized by microbes. This microbe conditioning makes leaves

Figure 11. Food Processing in Streams



Adapted from: Ken Cummins, “From Headwater Streams to Rivers,” *American Biology Teacher*, May 1977, p. 307.

into palatable, nourishing invertebrate meals before most other leaves are ready. Though they are somewhat slower to decompose than herbaceous leaves, alder leaves are also a favorite. Other types of leaves must remain in a stream longer before they become soft enough for the animals to eat, so shredders end up with a “time-release” menu.

Collectors are often more abundant than shredders in low-gradient streams.

By chewing on leaves, shredders expose leaf surfaces and edges to further attack by microbes. Shredders also biochemically alter organic substrates as the material passes through their digestive tracts. So, shredders excrete material usually composed of particles that are smaller and of a different quality than what they ate.

Many stonefly and caddisfly larvae are shredders. Caddisflies are especially intriguing because many use the same leaf bits and other organic fragments they eat to construct the cases in which they live.

Collectors

Collectors are animals that feed on particles of organic material less than 1 millimeter in diameter. These particles may not be very wide, but they are a mouthful for most collectors. One major food source for collectors is fecal pellets of other stream organisms. One group of collectors, called **filterers**, uses nets or mucus-coated fans to filter these small particles from the water. Others, **gatherers**, eat particles deposited or growing on the bottom of a stream channel.

Collectors eat algae, fragments of plants and animals, dissolved organic matter that has come together (flocculated) to form a particle, bacteria, and inorganic particles such as sand, in addition to the feces of shredders and other animals. Some

filterers and gatherers feed, at least for short periods, on particles of little or no nutritional value. Apparently, some appear to pay no attention to what they are eating.

Filter feeders include blackfly larvae—elongate animals that are bulbous near the bottom end where they attach themselves to stream substrates. Blackfly larvae have fans with which they strain particles from the water column. These fans are coated with a sticky substance that catches small particles that would otherwise pass through their fans.

Freshwater clams feed in a similar manner by passing food over mucous-covered gills that filter out small food particles. Some free-living caddisflies spin nets of various mesh sizes and thereby selectively collect particles of certain

In streams, organic materials are produced, received, stored and decomposed.

sizes. Mayfly nymphs and beetle and fly larvae are particularly abundant gathering collectors.

Collectors are often more abundant than shredders in low-gradient streams where fine particles are not washed away so rapidly. These streams provide pools and other areas where particles can settle out of the water. Fairly large numbers of collectors live all year long, unlike shredders, which are abundant during the fall in most streams.

Scrapers

Scrapers (sometimes called grazers) harvest algae and other materials from rocks and stream surfaces. Diatoms and other algae associated with these surfaces (*periphyton*) are generally most abundant in spring before leaves develop on overhanging tree limbs and block the sun. Periphyton also flourish in wide streams where the canopy does not stretch across the width. Algae will thrive again in autumn, in part

because more light and nutrients reach a stream after leaves fall. Predictably, the abundance of scrapers follows the same pattern.

Scrapers include certain mayfly larvae, some of which are flat. Their flatness lets them stay close to rock surfaces to avoid being swept away by swift currents. Some scrapers have suction disks on their abdomens. With these disks the insects can attach to surfaces and feed in rapidly flowing water where diatoms and other algae grow. Some scraper caddisflies construct their cases with small stones that afford the animals additional protection from the current.

Snails also harvest algae. They use feeding structures called radulae to rasp food from stone surfaces and to rasp at leaf surfaces.

Predators

Those invertebrates and other aquatic organisms, such as fish, that capture live members of other functional groups can be classified as **predators**. Predators may be among the first animals spotted in a sample collected from a stream because many of these animals, particularly predacious stoneflies, are comparatively active and conspicuously patterned or colored.

Crane fly larvae and odonates (dragonflies and damselflies) differ from stoneflies as predators because they are more non-descript and relatively inactive. Odonates often sit still and hidden (some bury themselves in sediment with only their eyes protruding) with their hinged, retractile mouthparts aimed at unsuspecting prey.

Predators can be subdivided into **piercers**, which suck the body fluids of their prey, or **engulfers**, which ingest their prey whole.

Diversity and adaptability

In streams, organic materials are produced, received, stored and decomposed. A large flood one year can introduce material from a floodplain. A fairly mild discharge another year can promote storage. Even nearby streams sometimes differ remarkably in gradient and riparian vegetation. The kinds and amounts of invertebrates vary along with each stream's characteristics. But the

*The similarity between
the types of invertebrates
the world over is striking.*

similarity between the types of invertebrates the world over is striking.

Dividing stream invertebrates into shredders, collectors, scrapers and predators is artificial, because some of these immature forms fit into more than one category. For example, scrapers may eat a lot of detritus while they graze algae. However, they may not grow as well or may pupate at a smaller size in areas where relatively less algae is available. Collectors may eat algae, bacteria, animals and sand. Some collectors also shred leaves, and some shredders can survive on fine particles when leaves are not available. But these distinctions are valuable. By looking at the feeding habits of these young invertebrates, you can begin to sort out different roles these animals play in the ecology of watersheds.

River continuum

Each year, large amounts of organic material fall into the headwaters of forested streams. Of this material, only 20% to 35% is flushed downstream. The remaining organic input is retained in the system and used by stream organisms. It can be processed by bacterial and fungal metabolic action, physical abrasion or consumed by insects. However it is processed, the debris is broken into smaller pieces, which increases the surface area of debris particles and subjects them to further degradation by microbial action.

In this way, small first- and second-order streams send partially prepared food into larger streams. Processing continues as small debris moves downstream through the system. A stream is a continuum that transports progressively smaller food materials.

The river continuum concept models running water systems. It describes biological communi-

ties in a stream that change in a somewhat predictable pattern from headwaters to the mouth. This pattern is influenced by:

- structure and gradient of the channel,
- bank stability,
- sediment loads,
- riparian habitats and cover,
- light penetration, and
- temperature.

Predictions work particularly well for forested mountain streams. As might be expected, with a model of this type, there are several exceptions to the pattern outlined in Figure 12 (p. 315). But the concept shows what might be expected in a stream system. If a factor does show up differently, it should act as a red flag, encouraging any researcher to question why it does not match the concept.

Adapted from Ken Cummins, *The Ecology of Running Waters: Theory and Practice*, pp. 287-290; and Jerry F. Franklin et al., *Ecological Characteristics of Old-Growth Douglas-fir Forests*, 1981, pp. 8-11.

Figure 12. The River Continuum

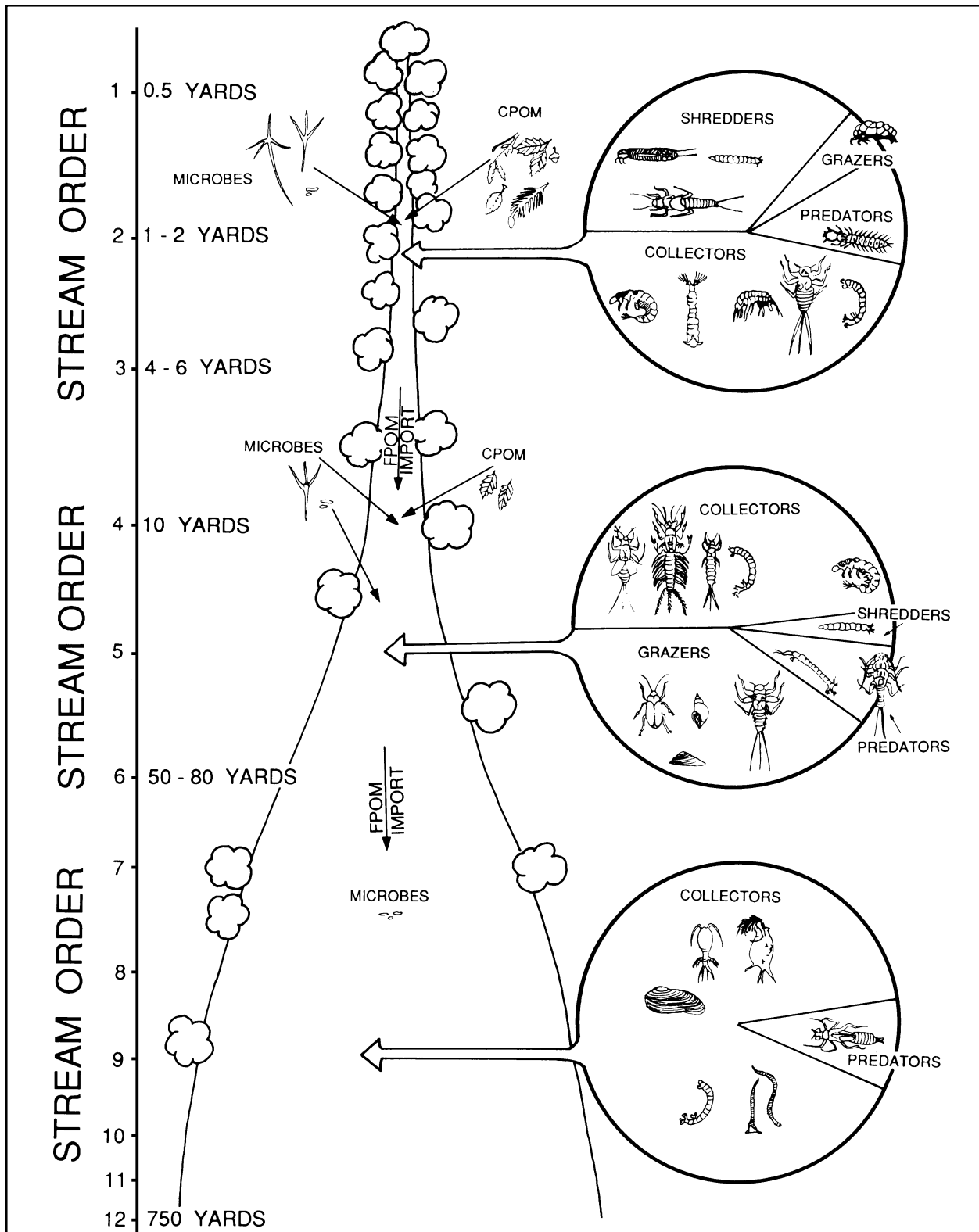
A diagram of the river continuum theory is shown at right. The forests at the headwaters (first- to third-order streams, see page 35) have less influence as a stream gets larger. With less input from the riparian habitat, the energy base relies more on algae that is produced from the opening of the canopy and on processed materials brought in from intermediate or midreach (third- to fifth-order) streams. As the kind of organic material changes, there is a decrease in the number of shredders and an increased number of collectors and scrapers (grazers).

The diversity of species that live in the midreaches of a stream system is greater than either upstream or downstream. The reason for this is not completely understood, but researchers have pointed out that midreach water temperatures can change more than

those of headwaters or larger rivers. The variety of organic substrates and physical components found in midreach streams can also have an effect.

Turbidity increases in the lower reaches (sixth- and higher-order streams) due to the greater loads of fine sediments from tributaries and downstream movement of processed particulate matter. Collectors dominate these reaches, and the diversity of other organisms decreases. Increased turbidity reduces light penetration and thereby reduces the efficiency and photosynthetic production of algae in larger streams. Large plankton communities are important in these areas. In summary, as the size of a stream changes, there is a shift in dominant organisms and the role they play.

Figure 12. The River Continuum



Source: Ken Cummins, "From Headwater Streams to Rivers," *The American Biology Teacher*, May 1977, p. 306.

Figure 13. Headwaters

The **headwaters**—or source—of a watershed are usually first- to third-order streams. These small streams constitute nearly 85% of the total length of running water in our country. Forested headwater streams receive significant organic debris from surrounding riparian habitat that heavily shades streams. As a result, small streams are generally **heterotrophic**, deriving most of their energy base from coarse organic input, rather than from aquatic plants. These streams are characterized by high gradients, low light and a fairly constant temperature. Under-

story vegetation is limited by heavy shading. An abundance of shredder invertebrate organisms are found because of large amounts of **coarse particulate**

organic matter (CPOM) falling into the stream. These streams are narrow, generally only 1½ feet to 20 feet in width.

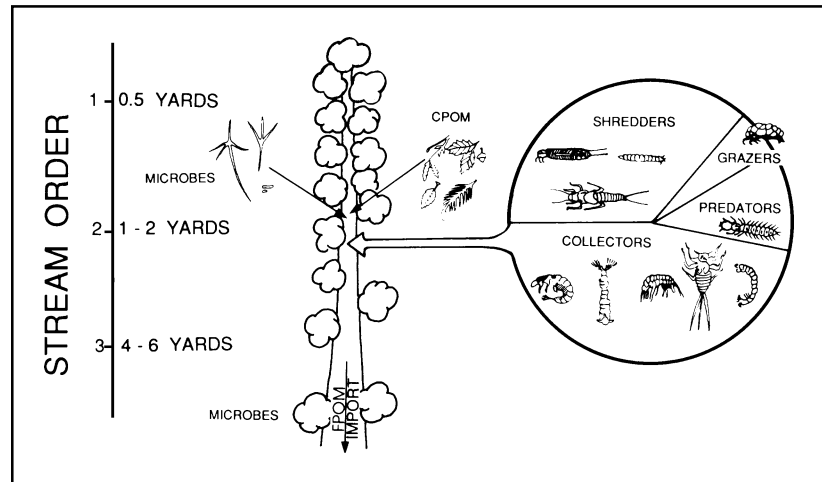


Figure 14. Midreaches

Midreaches are composed of third- to fifth-order streams. This size usually distinguishes streams from rivers. These streams are wider than headwater streams, often more than 30 feet. As a result, the riparian canopy does not cover the stream. Floodplain widths also increase.

Because the canopy is more open, more deciduous riparian vegetation is present and more sunlight reaches the water's surface. This allows an increase in primary photosynthetic production by algae and rooted plants. A shift from consumers to producers as the primary energy base of the stream occurs.

There is also a shift from coarse debris to **fine particulate organic matter (FPOM)** as the network of incoming headwater streams concentrates nutrients and partially processed particulate matter from upstream reaches. Less coarse

debris and more fine matter means a change from shredders to collectors in the invertebrate population of the stream. Greater biological diversity is found in these reaches than in either upstream or downstream areas.

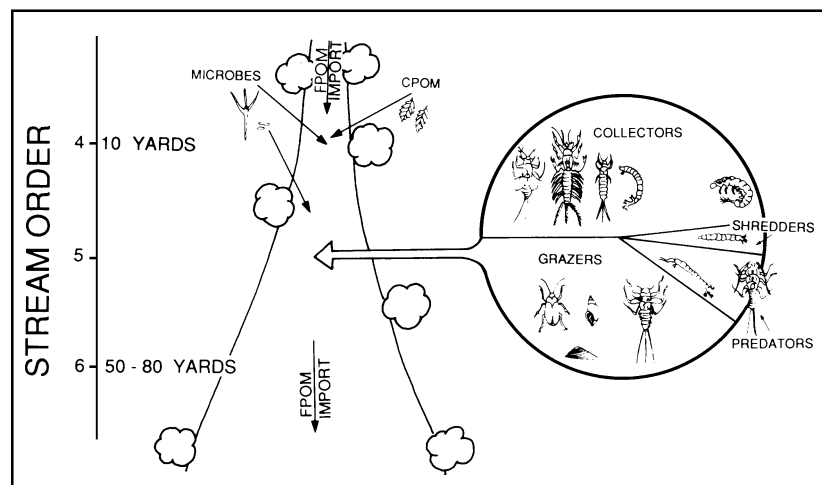


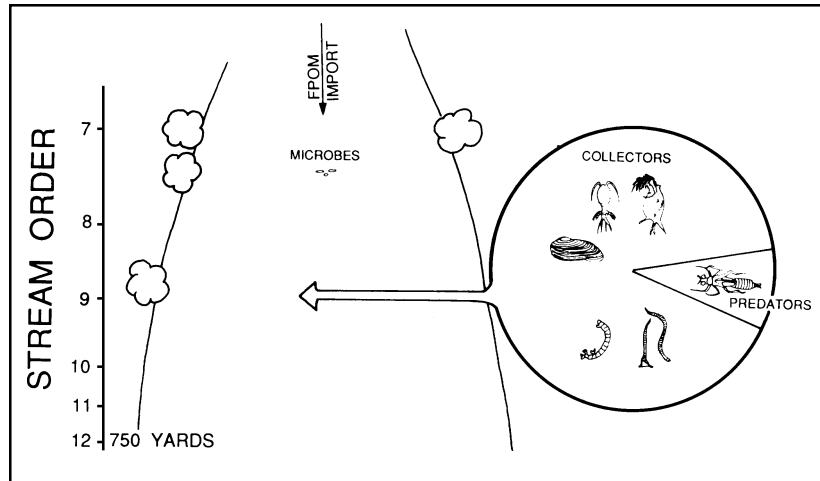
Figure 15. Large Rivers

Large rivers are sixth- to twelfth-order streams. Incoming particulates and fine sediments from upstream reaches increase turbidity in these streams. Murky water means less light penetration and a corresponding drop in productivity by algae and other aquatic plants. The energy base of a stream again shifts to consumers, relying on input from upstream waters.

Because of the prevalence of fine sediments, collectors are the dominant invertebrate life. Plankton and bottom-feeding fish are also common. There is little shading or daily tempera-

ture fluctuation in large rivers. The biological diversity is less than in the midreaches.

Few of these large rivers remain unaltered by human impoundments or pollution.



Extensions

1. "Are You Me?" *Aquatic Project WILD*, pp. 2.
2. "Blue Ribbon Niche," *Aquatic Project WILD*, pp. 52.
3. "Water Canaries," *Aquatic Project WILD*, pp. 24.

Bibliography

- Best, William. "Beneath Rivers: Another Realm." *Free Flow*, Winter 1990, original article in *Washington Post*, October 26, 1989.
- Cummins, Kenneth, W. "The Ecology of Running Waters: Theory and Practice." Hickory Corners, MI: Kellogg Biological Station, abstract, pp. 277-293, no date available.

Cummins, Kenneth W. "From Headwater Streams to Rivers." *American Biology Teacher*, 39 (5) May 1977, pp. 305-315.

Cummins, Kenneth W., and Margaret A. Wilzbach. *Field Procedures for Analysis of Functional Feeding Groups of Stream Macroinvertebrates*, Frostburg, MD: University of Maryland, 1985.

Cummins, Kenneth W., et al. *Stream Ecosystem Theory*. Stuttgart: International Association For Theoretical and Applied Limnology, December, 1984.

Elliott, J.M. "Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates." *Freshwater Biological Association, Scientific Publication No. 25*, Kendal, England: Titus Wilson and Son, Ltd., 1983.

Franklin, Jerry F., et al. *Ecological Characteristics of Old-Growth Douglas Fir Forests*. Washington, D.C.: U.S. Government Printing Office, 1981.

- Frear, Samuel T. "Ecological Benefits of Large Organic Debris in Streams." *Forest Research West*, Pacific Northwest Station, February 1982, pp 7-10.
- Gregory, Stan. "Stream Invertebrates and the Riparian Zone." presentation to Field Studies in Natural History, Corvallis (Oregon) High School, May, 1985.
- Hastie, Bill. "What Wiggles in Winter Water." *Oregon Wildlife*, December 1983, p. 15.
- Johnson, Phillip. "Learning the Language of a Stream." *National Wildlife*, August-September 1986, pp. 30-35.
- Kopec, John, and Stuart Lewis. *Stream Quality Monitoring*. Charleston, Oregon: Ohio Department of Natural Resources and Pacific Fisheries Enhancement, no date available.
- Maine, Neal. *Educator's Guide to Salmonid Museum*. Seaside, OR: Clatsop County Educational Services District, 1983.
- Maser, Chris, and James M. Trappe. *The Seen and Unseen World of the Fallen Tree*. Washington, D.C.: U.S. Department of the Interior, Bureau of Land Management, 1984.
- Mattingly, Rosanna L. "Turning Over a Wet Leaf." *The Science Teacher*, September, 1985.
- Minshall, G. Wayne, et al. "Interbiome Comparison of Stream Ecosystem Dynamics." *Ecosystem Dynamics: Ecological Monographs*, Vol. 53, 1983, pp. 1-25.
- Moody, Dwight. "Assessing Stream Water Quality." *American Biology Teacher*, September, 1985, pp. 359-361.
- Murdoch, Tom, et al. *Streamkeeper's Field Guide*. Everett, WA: Adopt-A-Stream Foundation, 1996
- Oregon State University Sea Grant College Program. "Sorting Freshwater Invertebrates." *Water, Water Everywhere*, Corvallis: Oregon State University, no date available.
- Peterson, R.C., and Cummins, K.W. "Leaf Processing in a Woodland Stream." *Freshwater Biology*, 1974, Vol. 4, p. 343.
- Poscover, Benjamin F. "More Thoughts on Stream Water Quality." *American Biology Teacher*, January, 1986, p. 6.
- Speaker, Robert, et al. *Analysis of the Process of Retention of Organic Matter in Stream Ecosystems*. Stuttgart: International Association for Theoretical and Applied Limnology, December 1984.
- Stoker, Daniel G., et al. *A Guide to the Study of Fresh Water Ecology*. Englewood Cliffs, NJ: Prentice-Hall, 1972.
- Vannote, Robin L., et al. "The River Continuum Concept." *Canadian Journal of Fisheries and Aquatic Science*, Vol. 37, 1980, pp. 130-137.

Build a “bug”

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

Students will (1) learn vocabulary associated with aquatic insects, including head, thorax, abdomen, anterior, posterior, lateral, and ventral, gills; (2) accurately use linear metric measurement; (3) and work in small groups and as a team to create a product.

Method

Students work in small teams to build an aquatic insect model out of simple materials.

For younger students

1. Change all measurements to standard English units and increase the size of the units to make it easier for smaller fingers to measure and cut out the pieces of their insect.
2. Provide a simplified drawing of an aquatic insect for students to reference while creating their own insect.
3. Collect a few large living specimens of aquatic insects, like large stoneflies or dragon flies. Place the insect in a clear glass bowl and set it on an overhead projector. Project the insect on the screen or wall and ask students to draw the specimen as they see it. Then, using a pointer, locate body parts and identify their locations (dorsal, ventral, lateral, anterior,

This activity is adapted from the original activity, “The Kneebone is Connected to the Legbone,” by Carolyn Hensley Johnson, Yamhill-Carlton (Oregon) Union High School, and is used with permission.

posterior). Label the insect as part of a group discussion.

Materials

Per group of three students

- set of three insect body part instructions on pp. 323-238 (one set per team: Insect A (stonefly) or Insect B (mayfly))
- small metric rulers (3)
- clear tape or glue stick
- color markers or colored pencils
- large paper sheets (easel pad sheets)
- scissors (3)
- aquatic insect drawing
- pencil (3)
- copies of student sheets (pp. 331-334)

Notes to the teacher

Although inaccurate, “bug” is a term often used to refer to any insect. Take time to instruct students that not all insects are bugs. Bugs are only those insects that belong to the Order Hemiptera, which means “half-winged.” Common examples would include water striders and stink bugs. The

Vocabulary

abdomen	mandible
antenna	maxillae
anterior	mesothorax
caudal	metathorax
centerline	ocelli
cerci	posterior
compound eye	proportional
dorsal	prothorax
gills	thorax
lateral	ventral
macroinvertebrates	wing pads

insects constructed in this activity are not true “bugs.” Stoneflies belong to the Order Plecoptera and mayflies belong to the Order Ephemeroptera.

The length of class time required to complete this activity varies widely with grade level, but count on at least 60 minutes. Each student in the group of three works on a different part of the insect. Measurement, interpretation, and following instructions are important aspects of this experience. In classrooms where use of the metric system is not an objective, you could convert the metric measurement to the nearest eighth, quarter, or full inch.

Make up enough sets of the insect cards so half of the groups receive instructions for Insect A and half receive instructions for Insect B. For durability, print the insect cards on card stock and laminate. Teams of three students receive one set of insect cards—either Insect A (a stonefly) or Insect B (a mayfly). Each set has instructions to construct a head, thorax and abdomen, with each on a separate page. Each student in the team receives one page of the instructions. The team can decide who will draw which part. When all segments are completed, the team glues or tapes them together to form an entire insect. Encourage students to decorate

their insects with camouflage colors, or the bright colors of some predators.

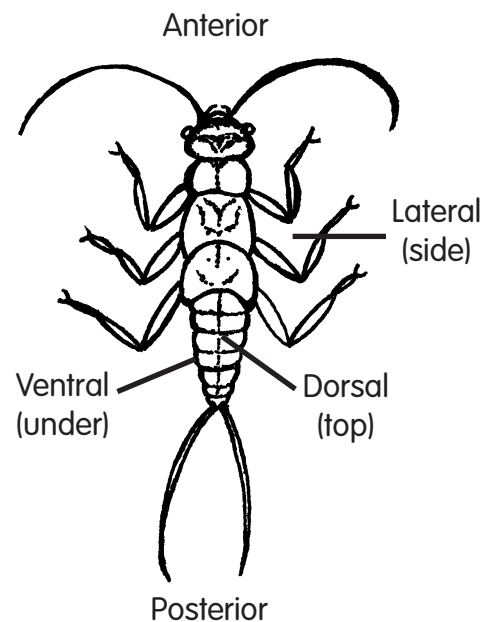
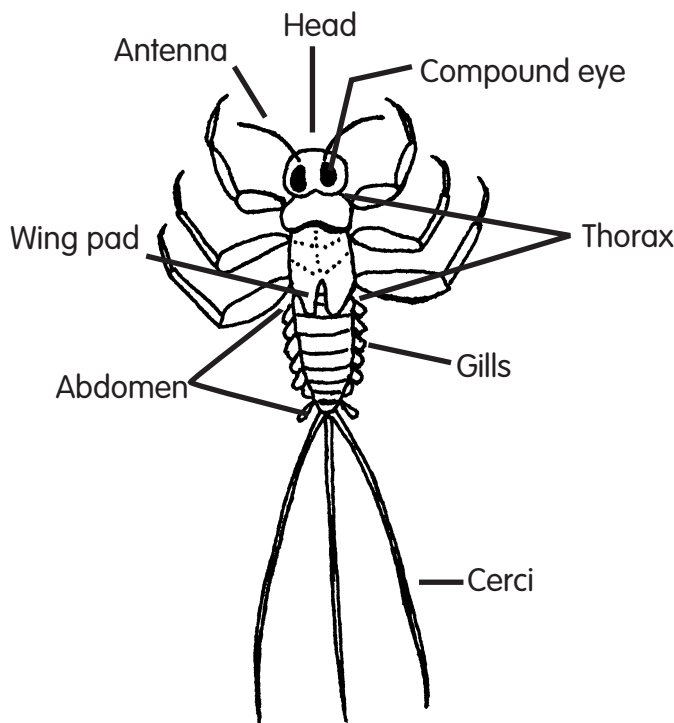
Once the teams have completed their insects, post them on the wall or window. Using the key on page 336, have each team determine the group to which their insect belongs. Then have each group present their insect, noting what group it belongs to and why.

Refer students to the vocabulary list to help them orient to the insect body parts. Some students may require a labeled diagram of an aquatic insect to ensure a more successful experience. One of the key objectives of this exercise is to translate and follow directions. The teacher may choose to not show the labeled diagrams so student work is clearly the result of interpretations rather than a copy of the accompanying diagrams.

Background

Do you know...

A study of streams would not be complete without a survey of the **macroinvertebrates** in the



stream. A large portion of those macroinvertebrates are insects—aquatic insects. These creatures live much of their lives in aquatic environments as larva before they emerge as adults to mate and lay eggs. Some aquatic insects live their entire lives in a stream or lake. This is a good thing for fish, because aquatic insects and other macroinvertebrates are important menu items for fish.

A survey of the aquatic insects in a stream can tell you much about the condition of the stream. Some species of aquatic insects have very low tolerances for polluted water or high temperatures, so if they are missing from the stream, you know there might be a water quality problem.

Aquatic insects are easy to identify if you know a few things about their body parts. Even a simple key will require you to know the difference between the head, thorax and abdomen of an insect before you can classify it into a group, like a stonefly, mayfly, or caddisfly.

Procedure

Now, it's your turn...

Not all insects are “bugs,” but because so many people use the term “bug” it is an easy habit to get into when talking about insects that live either on land or in water. One way to really get to know a stream is to look at the aquatic insect populations in that stream.

It can be really hard to identify aquatic insects without a basic knowledge of their body parts. The best way to learn about aquatic insect parts is to “build” an entire aquatic insect.

Get into groups of three. Each member of the group will build one of the major body parts of either a mayfly or a stonefly, two common aquatic insect types, (Stoneflies or mayflies are not true “bugs” even though they may be called that from time to time.) When the body parts are completed, attach them together to form a complete insect. If all of you have measured carefully, the head, thorax and abdomen should fit together to make your aquatic insect look **proportional**.

Insect terminology

abdomen: the posterior body part	appendages at the posterior end of some insects (cercus-singular)	ocelli: simple, light-sensitive eyes
antenna: sensory structures located on the head; usually segmented	compound eye: an eye made up of many separate visual units	posterior: situated behind; back end of a bilaterally symmetrical organism
anterior: situated before or in the front; front end of a bilaterally symmetrical organism	dorsal: back or upper side of an organism that has bilateral symmetry	prothorax: the anterior segment of the thorax
caudal: tail; situated in or directed to the hind part of the body	gill: filamentous respiratory structure in an aquatic animal	thorax: the body part located between the head and the abdomen
centerline: imaginary line in the apparent center of the insect dorsal side running the length of its body	lateral: situated on or coming from the side	ventral: lower side of an organism that has bilateral symmetry
cerci: a pair of small, sensory	mesothorax: the middle segment of the thorax	wing pads: areas on the thorax of many aquatic forms from which wings will develop in the adult insect
	metathorax: the posterior segment of the thorax	

- Each team will receive a set of three cards labeled “Insect A” or “Insect B.” The cards give detailed instructions for drawing the shape and size of the head, thorax, and abdomen of your insect.
- Pick up a large sheet of paper, a marker, a ruler, clear tape or a glue stick, scissors and a drawing of a generalized insect body for each team member.
- Draw your body part, then cut it out and put it together. You may want to color it prior to assembly, or after. Use the vocabulary list to help you with your drawing.
- When finished, put the parts together to form one insect. Be sure to put the parts together in the correct order. Label the parts, including the head, thorax and abdomen.
- Using the simple insect identification key on page 336, determine what kind of insect you created.

Insect A: Head

Using the following description, draw the head portion of Insect A. Be accurate in your measurements so the head will fit with the parts built by other team members.

- The head of this aquatic insect is shaped somewhat like a flattened, shortened pear, the narrow end being the most **anterior** on the insect.
- The head is 7.2 cm in length, and 8.4 cm in width at its widest point.
- Two **compound eyes**, one located on each side (laterally) and at the widest lateral point on the head, are 2.0 cm in diameter.
- The three **ocelli**, or eye spots, are located as the points of a triangle, with the top point (ocelli) located 1.2 cm from the front of the head along the **centerline**. The two other points of the triangle (ocelli) are located 2.8 cm from the anterior (front) of the head, each 0.8 cm from the **centerline**.

- The **antennae** are long segmented, pointed structures, each a total of 24 cm in length. Each segment is approximately 4 mm in length. The antennae taper toward the ends from a base width of 5 mm. They are attached to the dorsal side of the head anterior to the compound eyes and 2.8 cm from the **centerline** of the head.

After completing the head, label the parts.

The compound eyes, light-sensitive ocelli, and the antennae allow the insect to monitor its environment. The food gathering structures are located ventrally and are unseen in your model. These include the mandibles and maxillae. The **mandibles** are used for chewing or crushing food or may be modified for piercing or scraping. The **maxillae** are used for tearing or manipulating food, or they may be highly modified. These modifications allow certain groups of aquatic insects to move through coarse sediments and cling to exposed surfaces in rapidly flowing streams.

Insect A: Thorax

Using the following description, draw the thorax portion of Insect A. Be accurate in your measurements so the thorax will fit with the parts built by other team members.

- The mid region of the body, or **thorax**, bears the jointed legs and the wings. It is divided into three segments. The first segment bears the forelegs, the second segment bears the mid legs and fore wings, and the third segment the hind legs and hind wings (if wings are present). The jointed legs have five segments each.
- The first (most anterior) segment of the thorax is called the **prothorax**, and is shaped like a pillow. It is 10.8 cm wide and 8.0 cm long. The forelegs, composed of five segments, are 16.0 cm in length and are attached to the ventral (underside) side of the prothorax. They taper in width from 5.0 cm at the base to a point at the end. Branched filamentous gills are also attached to the ventral side of the prothorax, and appear as hair-like projections. (Make these by cutting strips of paper like the fringe.)
- The second segment of the thorax is called the **mesothorax**. It is somewhat square and 8.0 cm

on a side. The forewing pads, which are shaped like rabbit ears, are attached laterally to the mesothorax. Each wing pad is 12.0 cm in length and 3.2 cm at the widest point. (In the finished insect, these **wing pads** will overlap the hind wings pads on the third thorax segment.) The mid legs (composed of five segments) are attached to the ventral surface and are 14.0 cm in length. They taper in width from 4.0 cm at the base to a point at the end. Filamentous gills are also attached to the ventral side of the mesothorax. Again, they appear as hair-like projections.

- The third segment of the thorax is called the **metathorax**. It is rectangular in shape, 6.8 cm long and 8.0 cm wide. The hind wing pads are each 10.8 cm in length and 4.8 cm at the widest point, and are shaped like the forewing pads. The hind legs are attached to the ventral surface and are 16.0 cm in length. They taper in width from 5.0 cm at the base to a point at the end. Filamentous gills are also attached to the ventral side of the metathorax. They appear as hair-like projections.

After completing the thorax, label the parts.

Insect A: Abdomen

Using the following description, draw the **abdomen** portion of Insect A. Be accurate in your measurements so the abdomen will fit with the parts built by other team members.

- There are 11 abdominal segments, although in most adults, fusion of the last two makes them difficult to distinguish. Filamentous gills may be located on some segments of the abdomen. The end of the abdomen bears two cerci.
- The abdomen consists of 11 segments, with the first 10 rectangular in shape. They become progressively narrower toward the **posterior** end. Draw each segment using the following measurements:

- The 11th segment is shaped like a funnel, with the narrow part the most posterior. It is 6.8 cm long along the **centerline** and 3.6 cm at the anterior end.
- Two segmented **cerci** (tails) are attached to the lateral portions of the 11th segment. They are 18.0 cm long with each segment 4.0 cm in length. Each cerci is about 4 mm at the base and tapers to 1 mm.

After completing the abdomen, label the parts.

Segment	Length	Width
1	2.4 cm	7.2 cm
2	2.4 cm	7.0 cm
3	2.4 cm	7.0 cm
4	2.4 cm	6.8 cm
5	2.4 cm	6.8 cm
6	2.4 cm	6.4 cm
7	2.4 cm	6.0 cm
8	2.4 cm	5.6 cm
9	2.4 cm	5.2 cm
10	2.4 cm	4.4 cm

Insect B: Head

Using the following description, draw the head portion of Insect B. Be careful in your measurements so the head will fit with the parts built by other team members.

- The head of this aquatic insect is shaped somewhat like a rounded rectangle, wider than it is long. The **anterior** surface has a convex curve. It is 4.5 cm long and 8.0 cm wide.
- The two compound eyes are moderately large and are situated **laterally** and **dorsally** on the head. They are shaped like rounded gumdrops and are 3.0 cm in diameter.
- The three **ocelli**, or eye spots, are located in a line running laterally 1.6 cm from the head's anterior. One is on the **centerline**, and the other two are 1.2 cm on either side of the **centerline**.
- The **antennae** are long, segmented, pointed structures, each a total of 12.8 cm long. Each segment is approximately 4 mm long and from 5 mm to 3 mm wide. They are attached to the

dorsal side of the head anterior to the compound eyes and 2.8 cm from the **centerline** of the head.

After completing the head, label the parts.

Sensory structures are located on the dorsal side of the head and the food gathering structures are located ventrally. The compound eyes, light sensitive ocelli (simple eyes), and the antennae allow the insects to monitor their environment. The feeding apparatus is composed of the mandibles and maxillae. The mandibles are used for chewing or crushing the food or may be modified for piercing (piercing herbivores or predators) or scraping (scraping herbivores that graze on attached algae.). The maxillae are variously used for tearing and manipulating food, or they may be highly modified. These modifications allow certain groups of aquatic insects to move through coarse sediments and cling to exposed surfaces in rapidly flowing streams.

Insect B: Thorax

Using the following description, draw the thorax portion of Insect B. Be careful with your measurements so the thorax will fit with the parts built by other team members.

- The mid region of the body is called the **thorax**. It bears the jointed legs and the wings, and is divided into three segments: the prothorax, the mesothorax and the metathorax.
- The first segment is called the **prothorax**. It is shaped like a pillow and is 16.4 cm wide and 4.4 cm long. The forelegs, composed of five segments, are 16.0 cm long and are attached to the ventral side of the prothorax. They taper in width from 3 cm at the base to a point at the end.
- The second segment of the thorax is called the **mesothorax**. It is rectangular in shape and is 10.4 cm long and 13.2 cm wide. The mid legs have five segments, are attached to the ventral surface, and are 19.2 cm in length. They taper in width from 3 cm at the base to a point at the end. The forewing pads, shaped like rabbit ears, are attached laterally to the mesothorax. Each **wing pad** is 12.0 cm in length and 4.8 cm at the widest point. (In the finished insect, these wing pads overlap the hind wing pads.)
- The third segment is called the **metathorax**. It is rectangular in shape, 3.2 cm long and 12.8 cm wide. The hind legs (five segments) are attached to the ventral surface and are 22.8 cm long. They taper in width from 2.5 cm at the base to a point at the end. Each of the hind wing pads are 4.0 cm long and 2.8 cm at the widest point, and are attached posteriorly to the metathorax above the hind legs. After completing the thorax, label the parts.

After completing the thorax, label the parts.

Insect B: Abdomen

Using the following description, draw the abdomen portion of Insect B. Be careful in your measurements so the **abdomen** will fit with the parts built by other team members.

- There are 10 abdominal segments. **Gills** are located on segments one through seven, and are ping pong like in structure. The end of the abdomen bears three caudal filaments.
- The 10 segments of the abdomen are rectangular in shape. Draw each segment using the following measurements:
- Two gills are attached to the dorsal and lateral side of segments one through seven. Each gill is 4.8 cm long and 2.4 cm at the widest point. They are shaped somewhat like a ping pong paddle.
- Three caudal filaments are present, composed of two segmented **cerci** (tails) and a terminal filament. The two cerci are attached to the lateral portions of

the 10th segment. They are 25.0 cm long and segmented, with each segment 5 cm in length. The terminal filament is attached between the two cerci and is 27.0 cm long with similar segmentation. The cerci and terminal filaments are about 4 mm at the base and taper to 1 mm.

After completing the abdomen, label the parts.

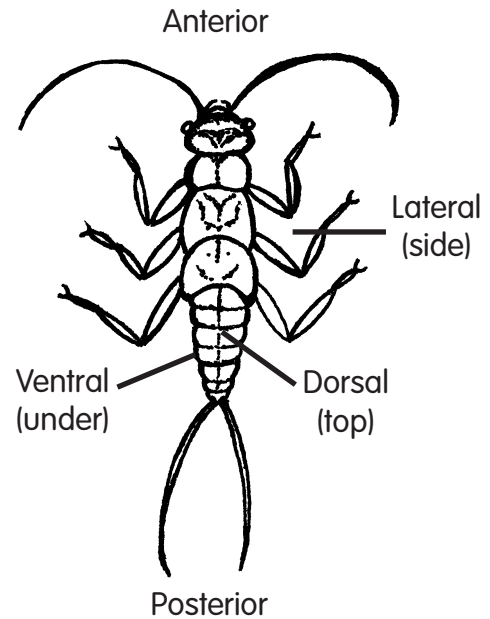
Segment	Length	Width
1	2.8 cm	10.4 cm
2	2.8 cm	10.4 cm
3	2.4 cm	10.8 cm
4	2.4 cm	12.0 cm
5	2.4 cm	12.0 cm
6	2.4 cm	12.0 cm
7	2.4 cm	11.2 cm
8	3.2 cm	10.0 cm
9	3.2 cm	6.8 cm
10	2.0 cm	4.0 cm

Questions

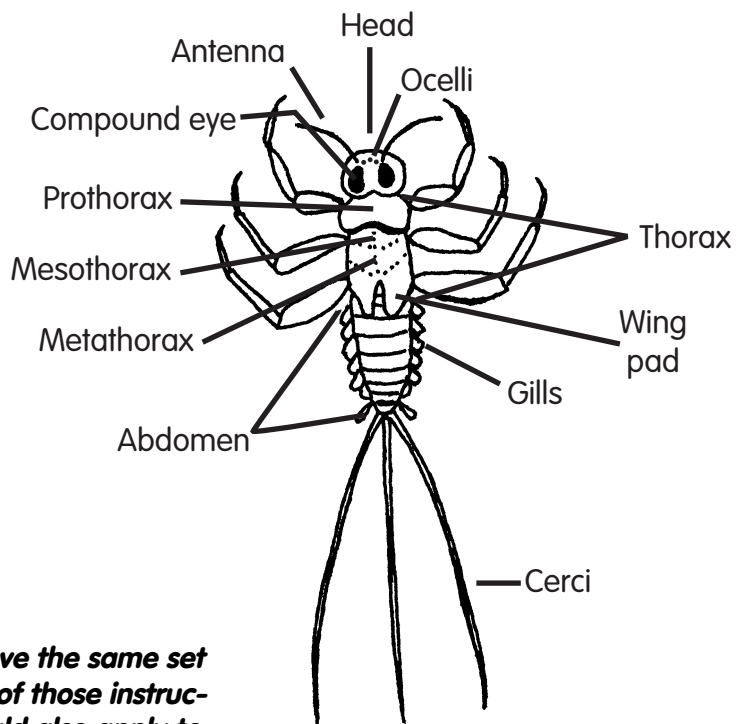
1. To what group of aquatic insects does your insect model belong?

Answers will vary, but should be either stonefly (Insect A) or mayfly (Insect B).

2. Label the following locations on the insect drawing to the right: anterior, posterior, dorsal, ventral, lateral.



3. Label the following body parts on the insect drawing below right: head, thorax, abdomen, cerci, compound eye, ocelli, gill, prothorax, mesothorax, metathorax, wing pads.



4. Which of the two aquatic insect groups in this activity (stoneflies or mayflies) has gills on the thorax? Which has gills on the abdomen?

Most stoneflies have thoracic gills and mayflies have abdominal gills.

5. What have you learned about reading and interpreting instructions in this activity? How might what you have learned apply to data collection?

Even though two or more groups have the same set of instructions, their interpretations of those instructions may be very different. This could also apply to data collected with the same sets of instructions. That is why it is very important that data collection instructions are very clear and understandable and that quality control measures are in place to reduce interpretation errors.

Going further

1. Now that students are familiar with insect body terminology, ask them to key out real aquatic insects using the key on page 336. Drawings or photos of aquatic insects would also work well.
2. Ask student teams to prepare a short natural history of their insect group or others and present it to the class.
3. Have students build an insect as before, using only a drawing or photo of an aquatic insect from a different group such as caddis flies, but on the same size scale as the one they just built.

Build a “bug”

Do you know...

A study of streams would not be complete without a survey of the **macroinvertebrates** in the stream. A large portion of those macroinvertebrates are insects—aquatic insects. These creatures live much of their lives in aquatic environments as larva before they emerge as adults to mate and lay eggs. Some aquatic insects live their entire lives in a stream or lake. This is a good thing for fish, because aquatic insects and other macroinvertebrates are important menu items for fish.

A survey of the aquatic insects in a stream can tell you much about the condition of the stream. Some species of aquatic insects have very low tolerances for polluted water or high temperatures, so if they are missing from the stream, you know there might be a water quality problem.

Aquatic insects are easy to identify if you know a few things about their body parts. Even a simple key will require you to know the difference between the head, thorax and abdomen of an insect before you can classify it into a group, like a stonefly, mayfly, or caddisfly.

This activity is adapted from the original activity “The Kneebone is Connected to the Legbone,” by Carolyn Hensley Johnson, Yamhill-Carlton (Oregon) Union High School, and is used with permission.

Now, it’s your turn...

Not all insects are “bugs,” but because so many people use the term “bug” it is an easy habit to get into when talking about insects that live either on land or in water. One way to really get to know a stream is to look at the aquatic insect populations in that stream.

It can be really hard to identify aquatic insects without a basic knowledge of their body parts. The best way to learn about aquatic insect parts is to “build” an entire aquatic insect.

Get into groups of three. Each member of the group will build one of the major body parts of either a mayfly or a stonefly, two common aquatic insect types, (Stoneflies or mayflies are not true “bugs” even though they may be called that from time to time.) When the body parts are completed, attach them together to form a complete insect. If all of you have measured carefully, the head, thorax and abdomen should fit together to make your aquatic insect look **proportional**.

- Each team will receive a set of three cards labeled “Insect A” or “Insect B.” The cards give detailed instructions for draw-

Vocabulary

abdomen	mandible
antenna	maxillae
anterior	mesothorax
caudal	metathorax
centerline	ocelli
cerci	posterior
compound eye	proportional
dorsal	prothorax
gills	thorax
lateral	ventral
macroinvertebrates	wing pads

ing the shape and size of the head, thorax, and abdomen of your insect.

- Pick up a large sheet of paper, a marker, a ruler, clear tape or a glue stick, scissors and a drawing of a generalized insect body for each team member.
- Draw your body part, then cut it out and put it together. You may want to color it prior to assembly, or after. Use the vocabulary list to help you with your drawing.
- When finished, put the parts together to form one insect. Be sure to put the parts together in the correct order. Label the parts, including the head, thorax and abdomen.
- Using the simple insect identification key provided by your teacher, determine what kind of insect you created.

Insect terminology

abdomen: the posterior body part

antenna: sensory structures located on the head; usually segmented

anterior: situated before or in the front; front end of a bilaterally symmetrical organism

caudal: tail; situated in or directed to the hind part of the body

centerline: imaginary line in the apparent center of the insect dorsal side running the length of its body

cerci: a pair of small, sensory

appendages at the posterior end of some insects (cercus-singular)

compound eye: an eye made up of many separate visual units

dorsal: back or upper side of an organism that has bilateral symmetry

gill: filamentous respiratory structure in an aquatic animal

lateral: situated on or coming from the side

mesothorax: the middle segment of the thorax

metathorax: the posterior segment of the thorax

ocelli: simple, light-sensitive eyes

posterior: situated behind; back end of a bilaterally symmetrical organism

prothorax: the anterior segment of the thorax

thorax: the body part located between the head and the abdomen

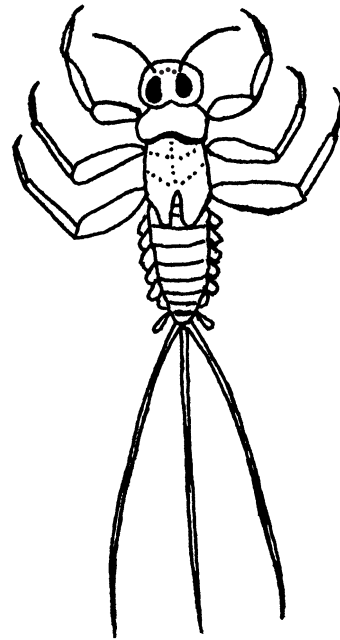
ventral: lower side of an organism that has bilateral symmetry

wing pads: areas on the thorax of many aquatic forms from which wings will develop in the adult insect

Student sheet

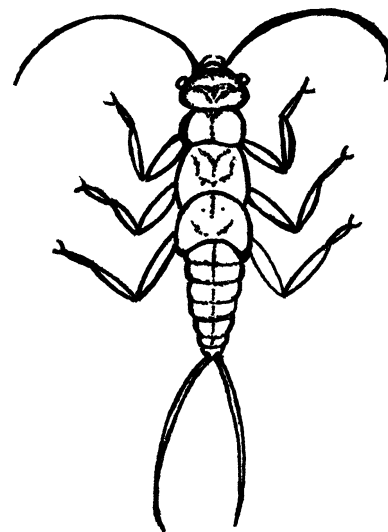
Questions

1. To what group of aquatic insects does your insect model belong?



2. Label the following locations on the insect drawing to the right: anterior, posterior, dorsal, ventral, lateral.

3. Label the following body parts on the insect drawing below right: head, thorax, abdomen, cerci, compound eye, ocelli, gill, prothorax, mesothorax, metathorax, wing pads.



4. Which of the two aquatic insect groups in this activity (stoneflies or mayflies) has gills on the thorax? Which has gills on the abdomen?

5. What have you learned about reading and interpreting instructions in this activity? How might what you have learned apply to data collection?

Student sheet

Water wigglers

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will (1) examine different instream microhabitats; (2) sort, count and record invertebrates from each microhabitat into functional feeding groups—shredders, collectors, scrapers, and predators; (3) calculate the percentage of each functional feeding group compared with the total number of insects observed by habitat type; and (4) analyze the data in accordance with stream type and general expectations for diversity based on background information.

Method

Students collect material from microhabitats within a determined reach of stream. Invertebrates are taken from these samples and sorted into feeding groups. A count is kept of each feeding group on the data sheet and the percentage of each group/habitat is calculated.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Vocabulary background is necessary. Some practice identification with different insect types would develop some familiarity with insects. Consider creating a student user guide as a knowledge base. Modify questions. If unable to travel to a body of water, you can collect and bring samples to the classroom for exploration.

Materials

- D-frame nets for collecting
- white enamel pans, photo developing trays, or other suitable light-colored shallow pans for general sorting
- 1-mm sieves (can be made from window screening)
- ice cube trays or other suitable containers for specific sorting
- forceps, probes, eye droppers, and small artist's paint brushes for picking up invertebrates
- razor blade or vegetable brush for scraping or scrubbing rocks
- copies of student sheets (pp. 345-352)
- identification guides

Notes to teacher

1. A diversity of different species distributed throughout the functional feeding groups, as opposed to an abundance of individuals in any one functional feeding group, is significant. For example, many different kinds of invertebrates versus a large number of one kind of species speaks for the diversity of organisms and the ability of the habitat to support that diversity (i.e., four different species of mayflies exhibit more diversity than four individuals of one species of mayfly).
2. Use *Field Procedures for Analysis of Functional Feeding Groups of Stream Macroinvertebrates* by Kenneth W. Cummins and

Vocabulary

coarse organic matter	predators
collectors	rocks
fine organic matter	scrapers
large wood	shredders

Margaret A. Wilzbach for keying organisms into functional feeding groups.

3. Should the data on the table show one particular organism or habitat type to be considerably out of line for expected ratios, be prepared to explain to students that occasionally, patchy distribution or inappropriate sample size may weight the data one way or the other. If it is too far off, it probably should be dropped from the data base with careful explanation.
4. Consider seasonality in assessing and observing aquatic invertebrate communities. Certain parts of the life cycle of some invertebrates may be missed. For example, at different times of the year scrapers would be most abundant during the summer when algae production is highest. Some have several generations per year. The life histo-

ries of these invertebrates are adapted to food availability. Whatever food resources are available influences which invertebrates will be found. Autumn is the best time for the greatest diversity of organisms for this activity.

5. Remember that functional feeding groups do not necessarily follow trophic levels. These categorizations simply describe how the organism gets its food.
6. If there are some aquatic insects you cannot identify in the field or if you want to do further sorting in the classroom, preserve the insects in a 70% ethyl alcohol solution (seven parts ethyl alcohol to three parts water) in a plastic or glass container with a screw-on cap. You can also create a reference collection of aquatic insects in this manner, using small vials to hold different insect types.

Aquatic Insect Guide

Builds a portable "house" or case to live in	Caddisfly
If case is made of material that was once living (wood, leaves, etc.)	Shredder
If case is made of mineral material (rocks, sand grains)	Scraper
Has two tails, without abdominal gills	Stonefly
If dark and uniformly colored	Shredder
If large and brightly colored and/or mottled	Predator
Has three tails (sometimes two), with abdominal gills	Mayfly
If flat, sometimes egg-shaped	Scraper
If cigar-shaped	Gathering Collector
Worm-like, without true legs	Flies
If <1 cm long, 1 pair stubby "legs," head well developed	Gathering Collector (Midge)
If >1.5 cm long, head reduced, often found in leaf litter	Shredder (Crane-fly)
Antennae modified as tiny fans	Filtering Collector (Blackfly)
Free-living, 3 pairs of legs	Odonates/Beetles
If large, with gills at end of abdomen	Predator (Damselfly, Dragonfly)
If no gills, usually tough outer covering, jaws often easy to see	Beetles
Dark brown; tough outer covering	Gathering Collector (Riffle Beetle)
Color varied; abdomen soft-bodied	Predator (Beetle)

Adapted from: Bill Hastie, "What Wiggles in Winter Water," *Oregon Wildlife*, December 1983, p. 15.

Background

Do you know . . .

Gazing into the cold water of a small stream in winter reveals little animal activity. The stream, like the woods around it, seems lifeless. But take a closer look. Skeletons of leaves with only the main ribs remaining provide evidence of animal activity. What happened to these leaves?

The leaves are eaten by aquatic invertebrates, especially insects, that spend most of their lives in water. They change their form, grow wings and emerge from water only during spring or summer when they mate.

During late fall and winter, small streams in wooded areas are menageries of aquatic insects. This is because most of the leaves and wood (containing energy for the insects) fall into the stream during this time. At other seasons of the year, you would probably find a different assemblage of animals.

If you were to gather a handful of leaf litter or a rock from the stream or kick up some bottom material from under rocks and let the current carry the material into a fine mesh net, you probably will collect a wide range of insects you probably had not known were present. These insects can be placed into groups according to how they feed (**functional feeding groups**) as explained below:

Shredders: Feed on leaves or wood that falls into streams and eat the softer plant material, leaving the leaf skeleton.

Collectors: Feed on fine material in streams. Some filter the water for their food (filtering collectors), while others burrow in the stream bottom, feeding as they go (gathering collectors).

Scrapers: Feed by scraping the surface of rocks and logs, removing algae.

Predators: Feed on insects and other invertebrate animals.

Use the guide (p. 336) to help you discover what kind of insects live in your stream. Remember, this is only a general guide; it will help you identify most insects to a particular group. Ask your instructor for other references.

Procedure

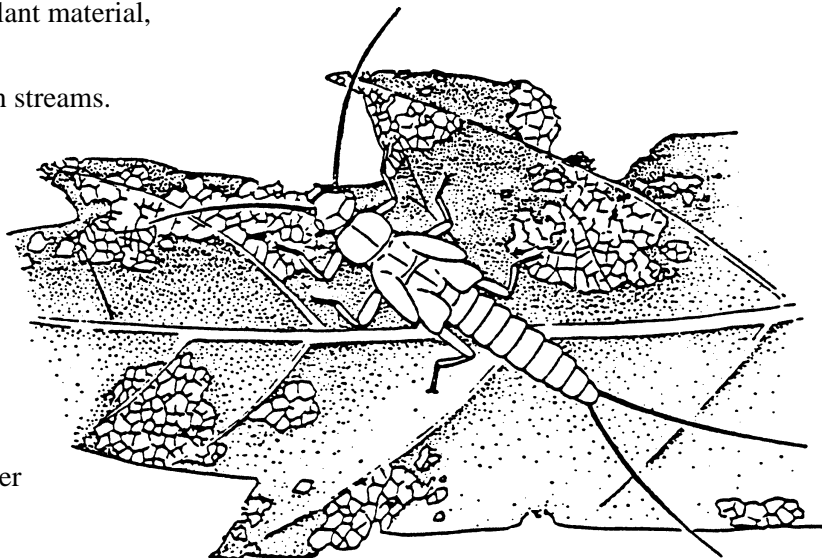
Now it's your turn . . .

If you have a cough, a fever, or a stomach ache, your mother usually figures that you are sick. After she determines that you're not faking it and trying to take a vacation from school, she usually lets you stay home for the day. The cough, fever, or stomach ache are indicators that something is wrong in your body.

Streams get sick, too. Poor land use practices and pollution in a stream's watershed (the area the stream drains) can lead to a stream health problem. How do biologists know when the stream starts to get sick? What are the indicators of poor stream health?

A stream that does not support as many fish as it once did is one indication. But even before changes in fish populations are noticed, biologists can tell if a stream is healthy or not by looking at the aquatic insects in the stream.

A stream with a diversity (many different kinds) of insects living in it is usually considered



healthy. But much can be learned about the stream by also looking at the kinds of insects living there. In general, insects can be placed in three groups.

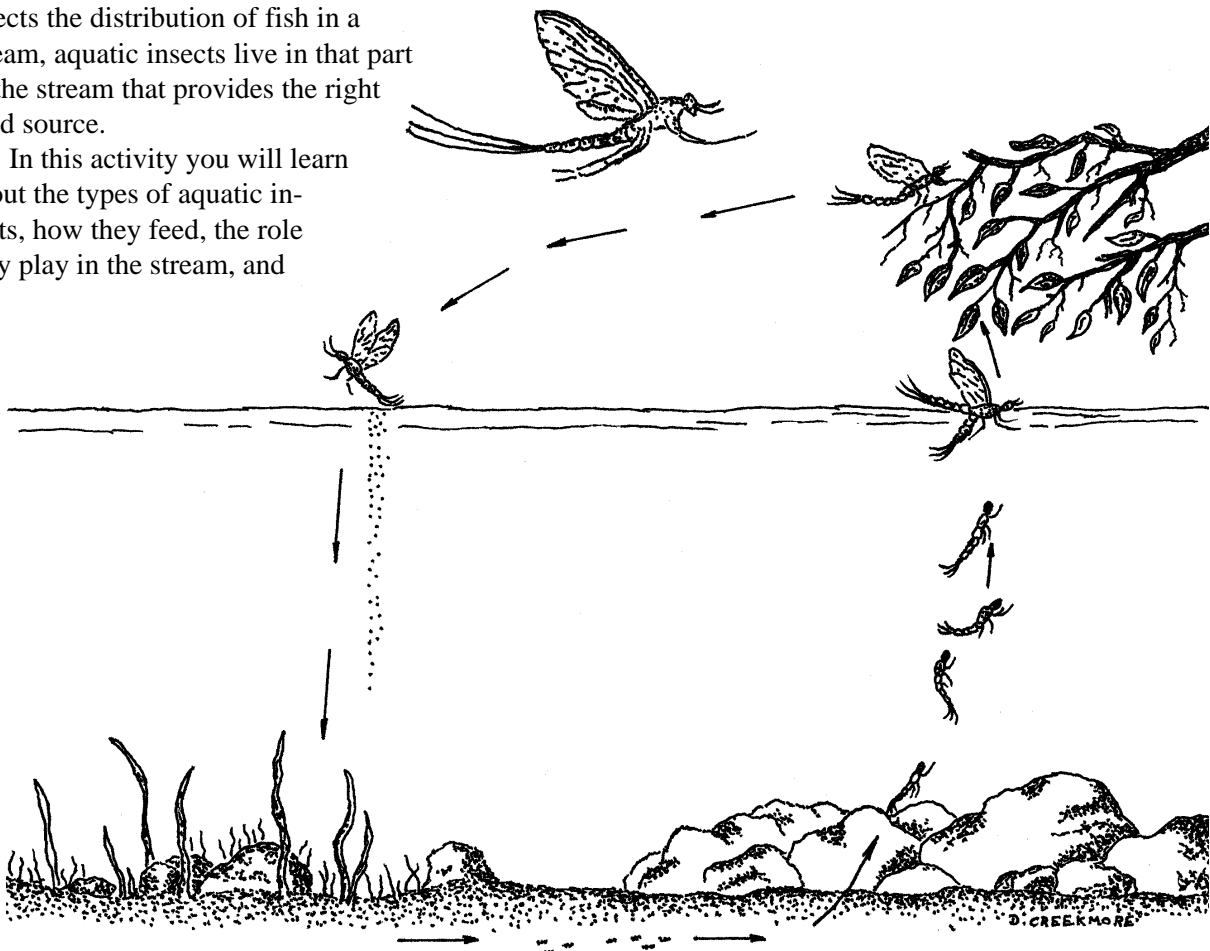
- Some insects cannot tolerate pollution so good numbers of these insects indicate good water quality. Caddisflies, stoneflies, and mayflies are examples of insects in this group.
- Other insects can live in a wide range of water conditions and to some degree can tolerate both good and poor water quality. Examples in this group are dragonflies, damselflies, beetles, and crane flies.
- Some insects can live in polluted water and good numbers of these insects indicate poor water quality. Midges and black flies are two examples in this group.

Aquatic insects are a major food source for fish. In the same way food availability affects the distribution of fish in a stream, aquatic insects live in that part of the stream that provides the right food source.

In this activity you will learn about the types of aquatic insects, how they feed, the role they play in the stream, and

what they can tell us about stream health.

1. When you arrive at the stream, look for different habitats where fish and insects live. Examples are **pools** where the water is deep and the surface is fairly quiet, **riffles** where the water is shallow and ripples over the rocks, and **backwaters** at the stream's edge that are shallow and quiet. These habitats are identified primarily by characteristics of water flow. The size of rocks in the stream, the amount of leaf or fine woody litter, and large woody debris (branches or logs) also help determine the distribution and abundance of invertebrates.
2. Use the following procedures to collect a sample from each of the habitat types—riffles, pools, and backwaters.
 - a. To avoid disturbing the sample area, approach the habitat type from the down-

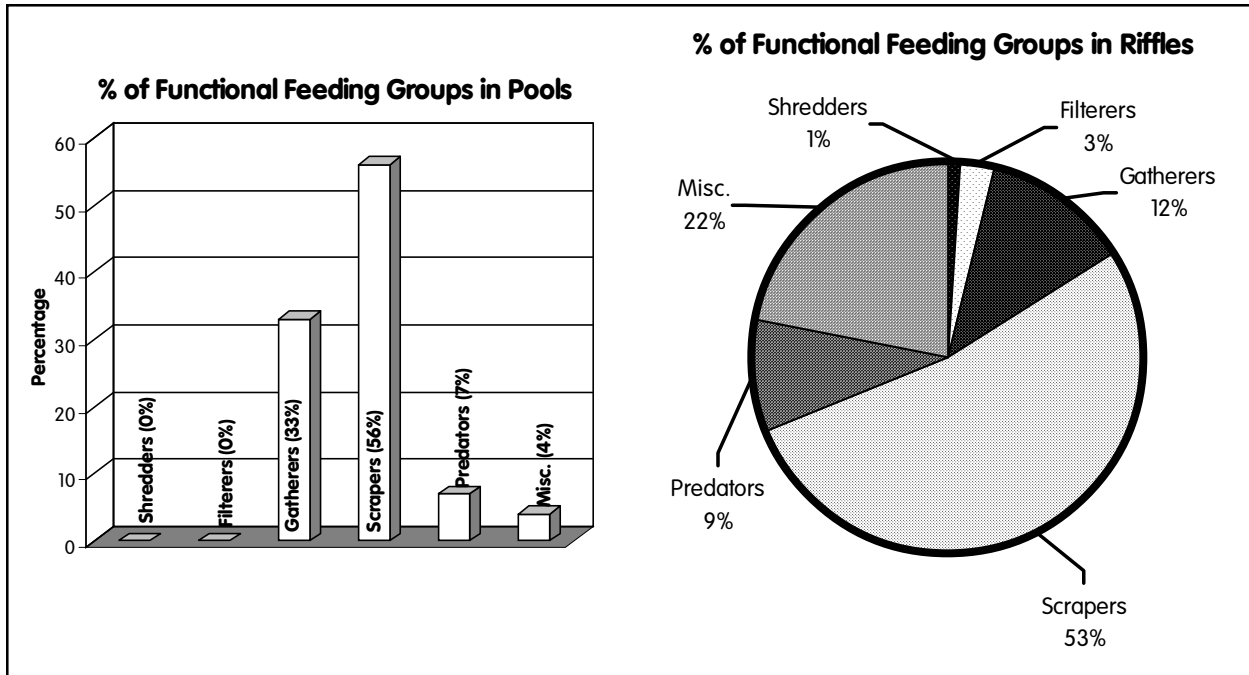


- stream end. Place the D-frame aquatic sampling net or other sampling device firmly on the bottom, perpendicular to the flow at the lower end of your sampling site.
- b. Collect a sample from a one square foot area immediately upstream from the net opening. Pick up any rocks that are more than 2 inches in diameter and while holding them underwater in front of the net, gently rub, scrape, or brush their surfaces so the water will carry any dislodged organisms into the net. Place “cleaned” rocks outside of the sample area.
 - c. If present include coarse organic matter (primarily leaf, needle, and fine wood litter) and pieces of water-logged branches and wood in your sample.
 - d. After larger rocks and debris have been rubbed and set aside, stir up the bottom of the one foot square sample area to a depth of at least 1 inches to 2 inches, allowing the current to carry particles and organisms into the net.
 - e. Collect at least three samples per habitat type (riffles, pools, backwaters) to get an average count per habitat.
3. Wash each sample into a 1-millimeter sieve. Then, wash the material from the sieve into a shallow white pan. Add just enough stream water to cover the sample.
 4. Use tape and a waterproof marker to label the sections of the sorting (ice cube) tray. Use labels like mayflies, stoneflies, caddisflies, beetle larvae, dragonflies, and others appropriate for the area you are sampling. You may need to consider subdividing some of the groups, for example, stony case caddisflies and organic case caddisflies. Fill the labeled ice cube tray with stream water. Using forceps, plastic spoons, eyedroppers, or small brushes gather the insects and place them in the appropriately labeled cube
 5. Use a dichotomous key to separate invertebrates into functional feeding groups: shredders, scrapers, filtering collectors, gathering collectors, and predators. (See page 336) or consult other similar guides.)
 6. Count the kinds of invertebrates and the numbers of each kind for each functional feeding group. Enter these numbers on the data sheet. Calculate the percentage of each group/habitat from the numbers.

To gain a better idea of the variety of organisms, list invertebrates within each functional feeding group by “kind.” Riffle beetles and mayflies are different kinds. If you can tell two different types within a “kind” (e.g., two different caddisflies), but do not know the specific names, simply list them as “caddisfly A” or “caddisfly B.”
 7. If possible, estimate the kinds and types of substrates where you sample and record on the data sheet *before* you collect the sample. An aquascope, or clear plastic mounted on the bottom end of a 5 gallon bucket or a long styrofoam box, will help cut surface water turbulence. Refer to the sizes listed on the chart for rock categories. Use the following categories for organic material:
 - Coarse organic matter (primarily leaf needle and fine wood litter >1 mm in diameter)
 - Fine organic matter (<1 mm to 0.45 mm)
 - Large wood (logs, stumps, branches)

For each sampling site list substrates as percentages (e.g., 25% sand, 50% cobble, 25% coarse organic matter). The total of all substrate types should equal 100%.

Example Bar and Pie Graphs



Analysis

The analysis compares samples, either as habitat types within a small stretch of stream (a reach), as different reaches along one stream, or even as samples from different streams.

- After sorting has been completed, calculate the percentage of each functional feeding group to the total. Total = number of shredders + filtering collectors + gathering collectors + scrapers + predators.

Example:

Habitat 1—Backwaters

of shredders = 10

Total invertebrates = 20

$$\frac{\text{Shredders}}{\text{Total}} \times 100 = \% \text{ shredders}$$

$$\frac{10}{20} \times 100 = 50\% \text{ shredders}$$

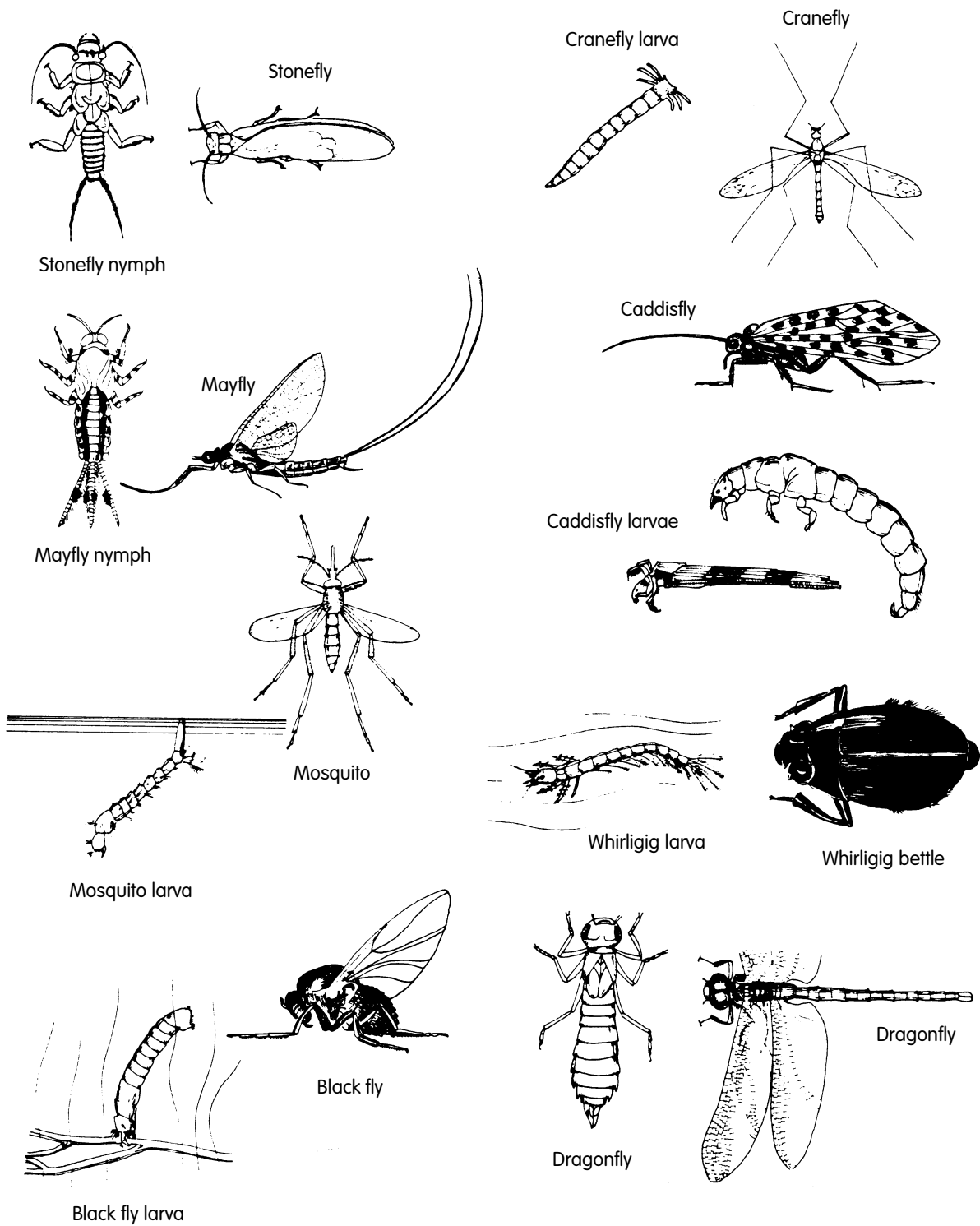
- Draw a bar or pie graph (see examples below) showing percentages for each functional feeding group for the each habitat type).

- Compare these graphs for all of your study all habitat types: riffles, pools, and backwaters. Consider whether the proportion of each functional feeding group fits what you might expect in each habitat. For example, when a lot of leaf litter is present, many shredders could be expected. In a sunny spot with an abundance of algae, more scrapers should be found.

Team members _____
 Date _____
 Stream _____
 Site _____

Data sheet for feeding groups *Numbers of organisms/functional feeding group*

	Habitat type:		Habitat type:		Habitat type:	
	Kinds	Numbers	Kinds	Numbers	Kinds	Numbers
Shredders						
Filtering collectors						
Gathering collectors						
Scrapers						
Predators						
Miscellaneous						
Substrate (% composition)	Boulders (>12")					
	Cobble (3"-12")					
	Gravel (0.2"-3")					
	Sand					
	Silt					
	Clay					
	Organic material					
Notes						



Source: 1987 Western Regional Environmental Education Council

Questions

1. Would a riffle habitat aquatic insect sample containing 1,000 blackfly larvae (filtering collector) show a greater diversity than one containing several species representative of all four functional feeding groups (shredders, grazers, collectors, and predators)? Why or why not?
No. Diversity means how many different kinds of things. One kind is not diverse. A habitat that can support a large variety of organisms has a greater potential for diversity than a habitat that supports large numbers of the same kind of organism.
2. What kind of stream habitat conditions could contribute to low aquatic insect diversity?
Lack of proper substrate, high sedimentation, little input of organic debris that serves as food for some aquatic insects, low water quality, high water temperature, low light conditions for algal growth that supports scrapers, plus others.
3. What kind of stream habitat conditions contribute to a high aquatic insect diversity?
Basically, habitat complexity. Optimal conditions include a variety of substrates, various flow conditions, cool water temperatures, little sedimentation, well-oxygenated water, a variety of organic debris and plants, plus others.
4. Which functional feeding group would you expect to be predominant in a small stream with a nearly closed canopy of deciduous trees? Why?
Shredders, because their primary role is to process the organic debris that falls into a stream.
5. A slow-moving, shallow stream with a muddy bottom would best support which functional feeding group? Why?
Collectors, especially gathering collectors that burrow in the stream bottom and feed on fine material.
6. Describe a stream situation that would illustrate prime habitat for the greatest diversity of aquatic insects.
Answers will vary, but should include components of the answer to question 3.

Going further

1. Use specific microhabitats such as coarse organic matter, fine organic matter, rocks, and large woody debris, or any other prevalent stream component to do the same functional group analysis. Use a uniform sample size for each habitat. This is a good approach for characterization of the whole stream.
2. Take a class walk to map out relative proportions of the stream occupied by each of the different habitat types. Using numbers derived from the “Water Wigglers” activity, calculate the relative abundance of invertebrates in a measured reach of stream.
3. In warmer months, allow students to snorkel to observe fish populations for an interesting and informative experience. Snorkeling may be used as an alternative to electrofishing to determine fish densities. **Snorkeling should not be done without proper supervision.**
4. To assess processing of coarse particulate matter, use a study of leaf packs. One or more types of leaves of dominant trees or shrubs from the riparian area should be collected just prior to autumn leaf fall and air

dried for at least a week.

Package the leaves into 5- to 10-gram packs, keeping track of beginning weights. When ready to do the activity, soak until softened, assemble and fasten loosely with heavy monofilament line or a large safety pin.

Label each pack with a separate number.

Place leaf packs in the stream facing into the current to simulate the natural accumulation of leaves on the upstream surface of obstructions such as logs and rocks.

At warmer temperatures, the packs should be evaluated about once each week and about once a month at colder temperatures.

Estimates of the percentage of leaf remaining and observations of the type of feeding activity that has occurred should be part of an evaluation. After observation, remove the remaining leaf packs and allow them to dry. Re-weigh and calculate the rate of processing.

Compare processing times for different types of leaves and relate this information to food processing in headwater streams (Peterson and Cummins, 1974).

5. "Using Stream Fish to Demonstrate Predator-Prey Relationships and Food Selection," *The American Biology Teacher*, Volume 49, No. 2, February, 1987, pp. 104-106
6. Make collections from streams that appear to be similar and dissimilar in size, gradient, riparian vegetation, or from the same stream at different seasons. Note trends and differences in types of animals present. Have students suggest reasons for these differences.
7. Ask students to hunt for the largest and smallest aquatic insects in their samples. Take this opportunity to discuss adaptations of each functional feeding group for the kinds of food they eat or lifestyle they lead.
8. See "Blue Ribbon Niche," *Aquatic Project Wild*, pp. 52.
9. Contact your local department of fish and wildlife, watershed council, or department of environmental quality office. Volunteer to assist with macroinvertebrate sampling on streams in your area. Ask local experts to show you how the data is collected, analyzed, and presented. Prepare a report and share this information with the class.

Water wigglers

Do you know . . .

Gazing into the cold water of a small stream in winter reveals little animal activity. The stream, like the woods around it, seems lifeless. But take a closer look. Skeletons of leaves with only the main ribs remaining provide evidence of animal activity. What happened to these leaves?

The leaves are eaten by aquatic invertebrates, especially insects, that spend most of their lives in water. They change their form, grow wings and emerge from water only during spring or summer when they mate.

During late fall and winter, small streams in wooded areas are menageries of aquatic insects.

This is because most of the leaves and wood (containing energy for the insects) fall into the stream during this time. At other seasons of the year, you would probably find a different assemblage of animals.

If you were to gather a handful of leaf litter or a rock from the stream or kick up some bottom material from under rocks and let the current carry the material into a fine mesh net, you prob-

Vocabulary

coarse organic matter	predators
collectors	rocks
fine organic matter	scrapers
large wood	shredders

Aquatic Insect Guide

Builds a portable "house" or case to live in	Caddisfly
If case is made of material that was once living (wood, leaves, etc.)	Shredder
If case is made of mineral material (rocks, sand grains)	Scraper
Has two tails, without abdominal gills	Stonefly
If dark and uniformly colored	Shredder
If large and brightly colored and/or mottled	Predator
Has three tails (sometimes two), with abdominal gills	Mayfly
If flat, sometimes egg-shaped	Scraper
If cigar-shaped	Gathering Collector
Worm-like, without true legs	Flies
If <1 cm long, 1 pair stubby "legs," head well developed	Gathering Collector (Midge)
If >1.5 cm long, head reduced, often found in leaf litter	Shredder (Cranefly)
Antennae modified as tiny fans	Filtering Collector (Blackfly)
Free-living, 3 pairs of legs	Odonates/Beetles
If large, with gills at end of abdomen	Predator (Damselfly, Dragonfly)
If no gills, usually tough outer covering, jaws often easy to see	Beetles
Dark brown; tough outer covering	Gathering Collector (Riffle Beetle)
Color varied; abdomen soft-bodied	Predator (Beetle)

Adapted from: Bill Hastie, "What Wiggles in Winter Water," *Oregon Wildlife*, December 1983, p. 15.

ably will collect a wide range of insects you probably had not known were present. These insects can be placed into groups according to how they feed (**functional feeding groups**) as explained below:

Shredders: Feed on leaves or wood that falls into streams and eat the softer plant material, leaving the leaf skeleton.

Collectors: Feed on fine material in streams. Some filter the water for their food (filtering collectors), while others burrow in the stream bottom, feeding as they go (gathering collectors).

Scrapers: Feed by scraping the surface of rocks and logs, removing algae.

Predators: Feed on insects and other invertebrate animals.

Use the guide (p. 345) to help you discover what kind of insects live in your stream. Remember, this is only a general guide; it will help you identify most insects to a particular group. Ask your instructor for other references.

Now it's your turn . . .

If you have a cough, a fever, or a stomach ache, your mother usually figures that you are sick. After she determines that you're not faking it and trying to take a vacation from school, she usually lets you stay home for the day. The cough, fever, or stomach ache are indicators that something is wrong in your body.

Streams get sick, too. Poor land use practices and pollution in a stream's watershed (the area the stream drains) can lead to a stream health problem. How do biologists know when the stream starts to get sick? What are the indicators of poor stream health?

A stream that does not support as many fish as it once did is one indication. But even before changes in fish populations are noticed, biologists can tell if a stream is healthy or not by looking at the aquatic insects in the stream.

A stream with a diversity (many different kinds) of insects living in it is usually considered healthy. But much can be learned about the

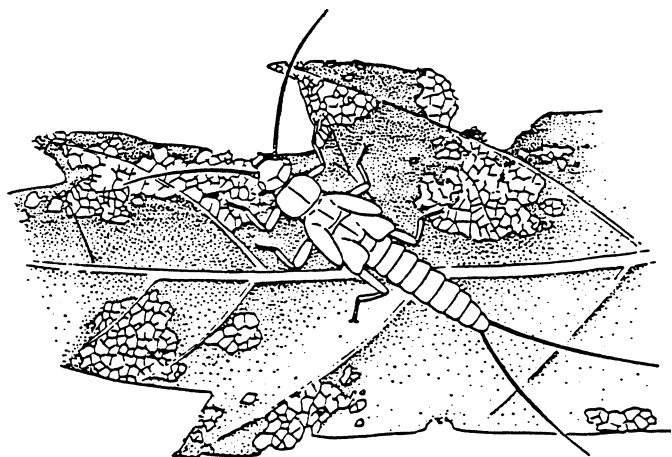
stream by also looking at the kinds of insects living there. In general, insects can be placed in three groups.

- Some insects cannot tolerate pollution so good numbers of these insects indicate good water quality. Caddisflies, stoneflies, and mayflies are examples of insects in this group.
- Other insects can live in a wide range of water conditions and to some degree can tolerate both good and poor water quality. Examples in this group are dragonflies, damselflies, beetles, and craneflies.
- Some insects can live in polluted water and good numbers of these insects indicate poor water quality. Midges and black flies are two examples in this group.

Aquatic insects are a major food source for fish. In the same way food availability affects the distribution of fish in a stream, aquatic insects live in that part of the stream that provides the right food source.

In this activity you will learn about the types of aquatic insects, how they feed, the role they play in the stream, and what they can tell us about stream health.

1. When you arrive at the stream, look for different habitats where fish and insects live. Examples are **pools** where the water is deep and the surface is fairly quiet, **riffles** where the water is shallow and ripples over the rocks, and **backwaters** at the stream's edge that are shallow and quiet. These habitats are identified primarily by characteristics of



Student sheet

water flow. The size of rocks in the stream, the amount of leaf or fine woody litter, and large woody debris (branches or logs) also help determine the distribution and abundance of invertebrates.

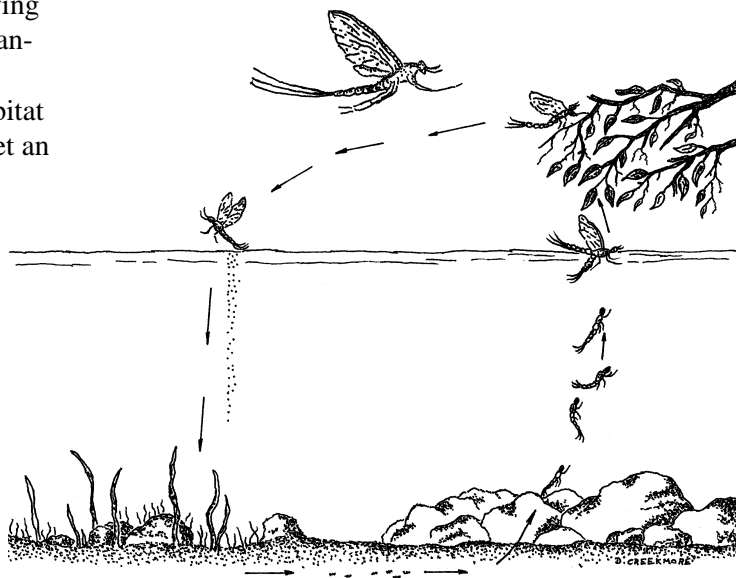
2. Use the following procedures to collect a sample from each of the habitat types—riffles, pools, and backwaters.
 - a. To avoid disturbing the sample area, approach the habitat type from the downstream end. Place the D-frame aquatic sampling net or other sampling device firmly on the bottom, perpendicular to the flow at the lower end of your sampling site.
 - b. Collect a sample from a one square foot area immediately upstream from the net opening. Pick up any rocks that are more than 2 inches in diameter and while holding them underwater in front of the net, gently rub, scrape, or brush their surfaces so the water will carry any dislodged organisms into the net. Place “cleaned” rocks outside of the sample area.
 - c. If present include coarse organic matter (primarily leaf, needle, and fine wood litter) and pieces of water-logged branches and wood in your sample.
 - d. After larger rocks and debris have been rubbed and set aside, stir up the bottom of the one foot square sample area to a depth of at least 1 inches to 2 inches, allowing the current to carry particles and organisms into the net.
 - e. Collect at least three samples per habitat type (riffles, pools, backwaters) to get an average count per habitat.
3. Wash each sample into a shallow white pan. Add just enough stream water to cover the sample.
4. Use tape and a waterproof marker to label the sections of the sorting (ice cube) tray. Use labels like mayflies, stoneflies, caddisflies, beetle larvae, dragonflies, and others appropriate for the area you are sampling. You may need to consider subdividing

some of the groups, for example, stony case caddisflies and organic case caddisflies. Fill the labeled ice cube tray with stream water. Using forceps, plastic spoons, eyedroppers, or small brushes gather the insects and place them in the appropriately labeled cube

5. Use a dichotomous key to separate invertebrates into functional feeding groups: shredders, scrapers, filtering collectors, gathering collectors, and predators. (See page 345 or consult other similar guides.)
6. Count the kinds of invertebrates and the numbers of each kind for each functional feeding group. Enter these numbers on the data sheet. Calculate the percentage of each group/habitat from the numbers.

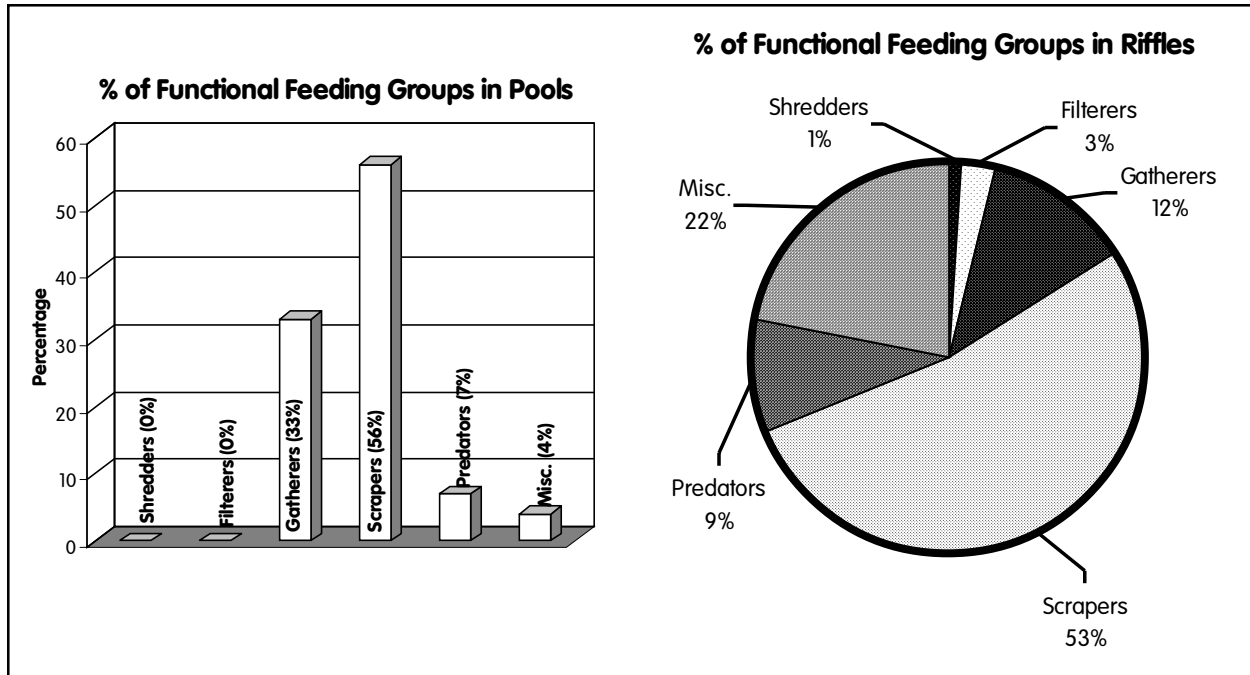
To gain a better idea of the variety of organisms, list invertebrates within each functional feeding group by “kind.” Riffle beetles and mayflies are different kinds. If you can tell two different types within a “kind” (e.g., two different caddisflies), but do not know the specific names, simply list them as “caddisfly A” or “caddisfly B.”

7. If possible, estimate the kinds and types of substrates where you sample and record on the data sheet *before* you collect the sample. An aquascope, or clear plastic mounted at the end of a long 5 gallon bucket or a styrofoam box, will help cut surface water turbulence.



Student sheet

Example Bar and Pie Graphs



Refer to the sizes listed on the chart for rock categories. Use the following categories for organic material:

- Coarse organic matter (primarily leaf needle and fine wood litter >1 mm in diameter)
- Fine organic matter (<1 mm to 0.45 mm)
- Large wood (logs, stumps, branches)

For each sampling site list substrates as percentages (e.g., 25% sand, 50% cobble, 25% coarse organic matter). The total of all substrate types should equal 100%.

Analysis

The analysis compares samples, either as habitat types within a small stretch of stream (a reach), as different reaches along one stream, or even as samples from different streams.

- After sorting has been completed, calculate the percentage of each functional feeding group to the total. Total = number of shredders + filtering collectors + gathering collectors + scrapers + predators.

Example:

Habitat 1—Backwaters

of shredders = 10

Total invertebrates = 20

$$\frac{\text{Shredders}}{\text{Total}} \times 100 = \% \text{ shredders}$$

$$\frac{10}{20} \times 100 = 50\% \text{ shredders}$$

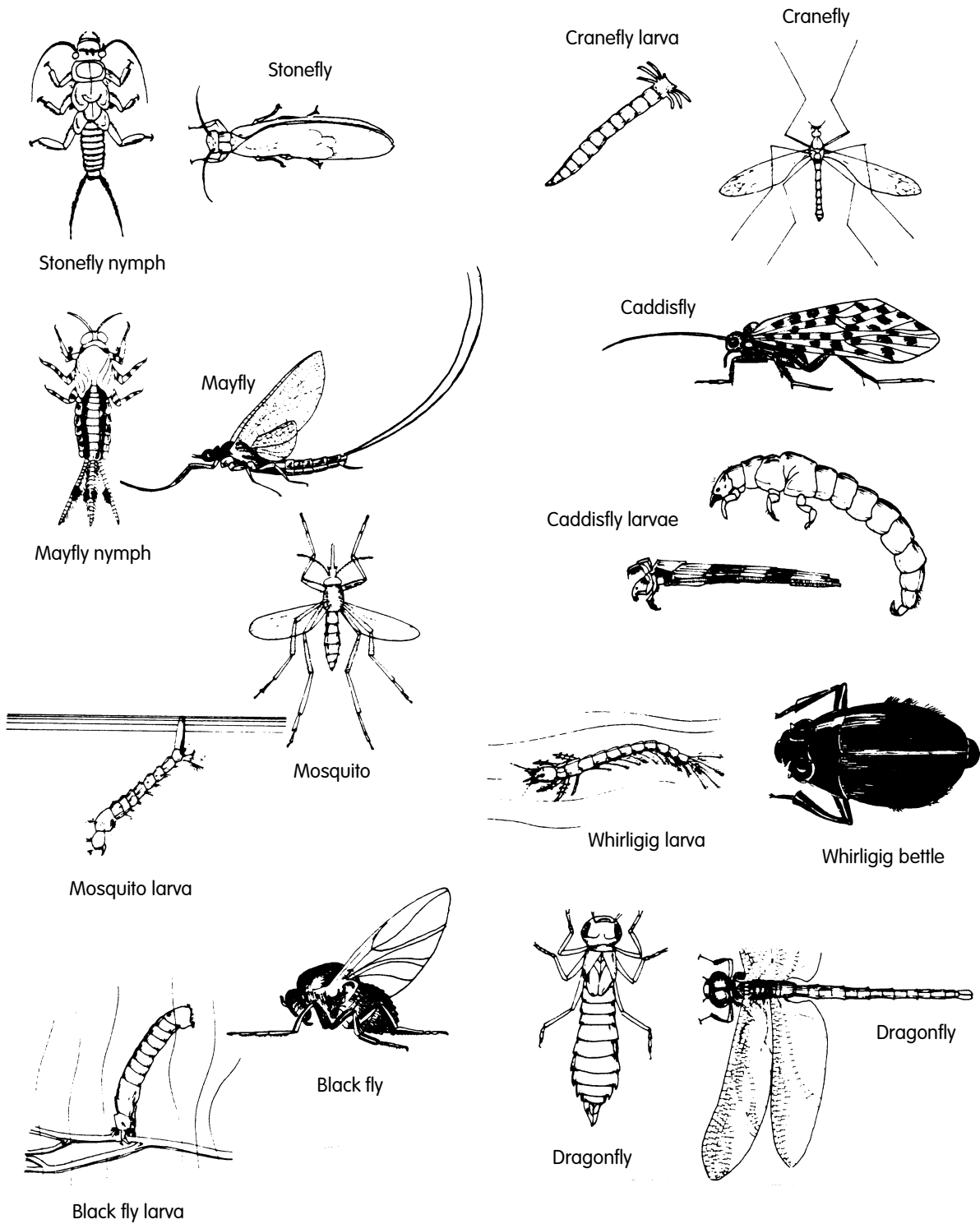
- Draw a bar or pie graph (see examples below) showing percentages for each functional feeding group for the each habitat type).
- Compare these graphs for all of your study all habitat types: riffles, pools, and backwaters. Consider whether the proportion of each functional feeding group fits what you might expect in each habitat. For example, when a lot of leaf litter is present, many shredders could be expected. In a sunny spot with an abundance of algae, more scrapers should be found.

Student sheet

Team members _____ Date _____
 Stream _____
 Site _____

Data sheet for feeding groups *Numbers of organisms/functional feeding group*

	Habitat type:		Habitat type:		Habitat type:	
	Kinds	Numbers	Kinds	Numbers	Kinds	Numbers
Shredders						
Filtering collectors						
Gathering collectors						
Scrapers						
Predators						
Miscellaneous						
Substrate (% composition)	Boulders (>12")					
	Cobble (3"-12")					
	Gravel (0.2"-3")					
	Sand					
	Silt					
	Clay					
	Organic material					
Notes						



Source: 1987 Western Regional Environmental Education Council

Student sheet

Questions

1. Would a riffle habitat aquatic insect sample containing 1,000 blackfly larvae (filtering collector) show a greater diversity than one containing several species representative of all four functional feeding groups (shredders, grazers, collectors, and predators)? Why or why not?
2. What kind of stream habitat conditions could contribute to low aquatic insect diversity?
3. What kind of stream habitat conditions contribute to a high aquatic insect diversity?
4. Which functional feeding group would you expect to be predominant in a small stream with a nearly closed canopy of deciduous trees? Why?
5. A slow-moving, shallow stream with a muddy bottom would best support which functional feeding group? Why?
6. Describe a stream situation that would illustrate prime habitat for the greatest diversity of aquatic insect .

Student sheet

Salmon life cycle

9.2

“... the fish is as clever as any creature could be in its position.”

— Richard Jeffries

Eggs

The life cycle of a salmon or other **anadromous** fish begins when **eggs** are deposited and fertilized in the gravel of a stream. Successful reproduction depends on an adequate supply of gravel with low sediment content. The gravel protects eggs during incubation.

About one month after being deposited (although this varies, depending upon water temperature), eyes begin to show. During incubation, water flow (to deliver oxygen and carry away waste products) and temperature (40°F to 65°F) must be suitable. **Salmonids** are cold-water fish and generally cannot tolerate temperatures above 68°F. The greatest mortality in a salmon’s life cycle occurs during the egg-to-fry stage.

Alevins

In late winter or spring, the eggs hatch. Young fish, called **alevins**, rapidly grow under the gravel for one to three months. An alevin is a fragile creature with huge eyes and a large yolk sac protruding from its belly. The orange sac contains a completely balanced diet that lasts for several months. The **vitelline vein** runs through the center of the sac and picks up oxygen from water.

Fish at this stage are protected from most predators and other hazards by remaining under the gravel. A flow of water is critical to alevin survival. Porous gravel provides a stable streambed and allows good percolation of oxygen-rich water.

Fry

Alevins absorb their yolk sacs and emerge from the gravel as **fry** in late spring and summer. About an inch long, they are easy prey for larger fish. Chinook, sockeye, coho salmon and steelhead may spend a year or more in streams or lakes, while chum salmon begin to migrate directly to the sea.

The greatest mortality in a salmon’s life cycle occurs during the egg-to-fry stage.

Fry feed on plankton and small insects. At this stage, streamside cover is needed for protection from predators and temperature extremes and as a source of food.

Vocabulary

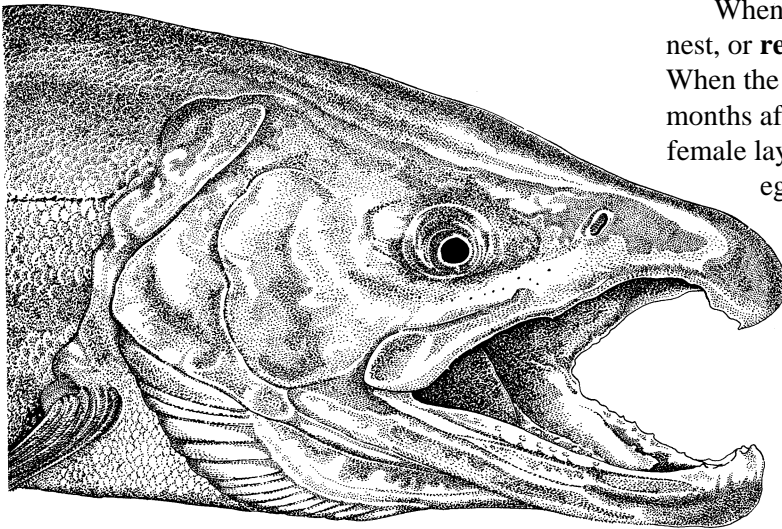
alevins	redd
anadromous	salmonids
eggs	smoltification
fry	smolts
milt	spawn
parr marks	vitelline vein

Smolts

After spending time in freshwater, the 4- to 6-inch fish, known as **smolts**, head to the sea with fall or spring freshets. **Smoltification** requires physiological changes enabling the fish to survive the drastic change from fresh to salt water. In addition, the **parr marks** disappear as the smolt becomes silvery and more distinctly counter-shaded (dark above, light below) to survive ocean conditions. Water flow is again a critical factor during downstream smolt migration.

High flows mean higher survival rates. On some streams, dams alter the natural flows of river systems as they store spring runoff. Decreased flows can increase the amount of time it takes smolts to reach the ocean and affect their ability to adjust to salt water conditions. A delay can increase their susceptibility to predators and disease. Smolts are also lost as a result of passing into unscreened irrigation ditches, becoming stranded in a field. Smolts can also be injured or killed as they pass through hydroelectric facilities or fail to find passageways at dams.

Anadromous salmonids spend varied amounts of time in the sea, up to five years, depending on the species. While in the ocean, usually near the Gulf of Alaska, salmon grow rapidly by feeding on the rich, available food supply. Plankton makes up their first food source. As the fish grow, shrimp, anchovies and herring make up the majority of their diet.



Sharks, marine mammals and other predators take a portion of the maturing salmon as food. Commercial and sports fisheries also harvest fish.

Adult salmon

Usually in early summer of their maturing year, salmon begin to head back to their home streams. While their exact method of navigation is not fully understood, researchers believe salmonids navigate by electromagnetic signals, the moon and stars, the smell of their home stream, or a combination of these factors. Salmon stop feeding when they enter fresh water and live on stored body fats for the rest of the trip.

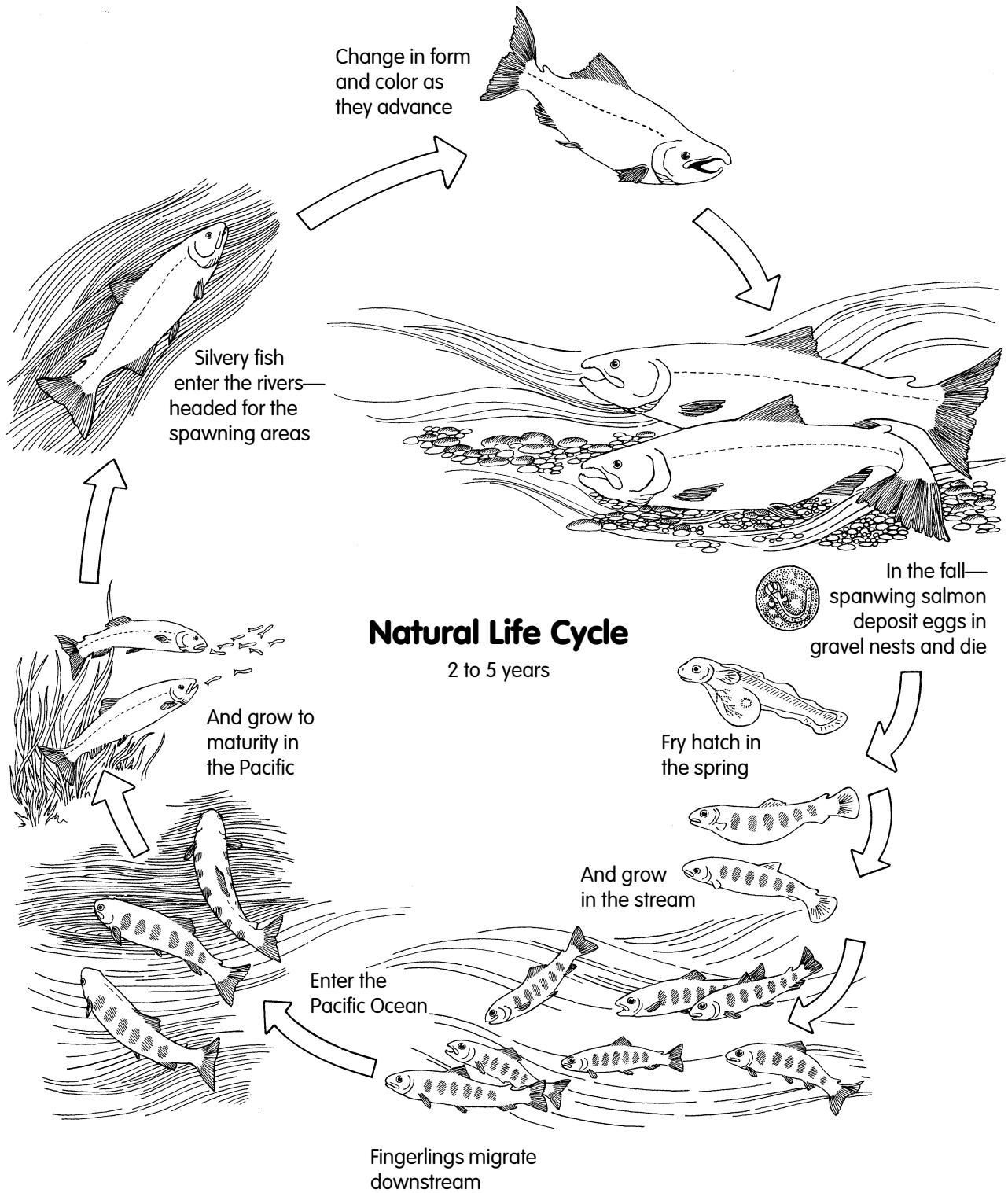
Anglers, natural predators, and other hazards continue to reduce salmon numbers on their way to the spawning beds of their home stream.

Hydroelectric dams block passage upriver. Most dams now have fish passages, but finding them uses part of the salmon's limited energy supply. Log jams, landslides or other obstructions occasionally restrict passage. Waterfalls, road culverts and velocity barriers also create migration problems for salmon.

When flows are too low for upstream movement, water temperatures can become quite warm in the holding pools and cause conditions promoting disease outbreaks. Restricted flows can hold salmon for too long, reducing their chances for successful spawning when they finally reach the spawning beds.

When ready to **spawn**, the female digs a nest, or **redd**, up to 16 inches deep in the gravel. When the nest is ready, which can be weeks or months after they reach the gravel beds, the female lays her eggs. She deposits 3,000 to 8,000 eggs in the redd. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains sperm. The female covers the eggs with gravel to complete the spawning process.

After spawning, the adult salmon's life is finished. Within a short time it dies, and the carcass drifts downstream, decaying and contributing its



Length of life cycle varies with species and consitions

nutrients to the stream from which it originally arose. Not all steelhead die after spawning, but because of their weakened condition, the percentage of adults that live to return to spawn again is very small.

Extensions

1. "Hooks and Ladders," *Aquatic Project WILD*, pp. 43. Grades 3-9.
2. *Discovering Salmon: A Learning and Activity Book*, Nancy Field and Sally Machlis, Dog-eared Publications, P.O. Box 814, Corvallis, OR 97339, 1984. Grades K-6.
3. "Sniffin' Salmon," *Water, Water Everywhere Curriculum Project*, Newport OR: OSU Hatfield Marine Science Center. Grades 3-9.
4. "Comings and Goings of Coho" *Water, Water Everywhere Curriculum Project*, Newport OR: OSU Hatfield Marine Science Center. Grades 3-9.
5. "Where Have All the Salmon Gone?" *Aquatic Project WILD*, pp. 166. Grades 6-12.

Bibliography

- Borton, Wendy, et al. *Clean Water, Streams, and Fish: A Holistic View of Watersheds*. Seattle: Municipality of Metropolitan Seattle, no date available.
- Brown, Bruce. *Mountain in the Clouds: The Search for Wild Salmon*. New York: Simon and Schuster, Inc., 1982.
- Claire, Errol. "Twenty-Seven Year Summary of Chinook Salmon Spawning Density." John Day District, 1959-1986," (mimeographed).
- Curtis, Ruth. "The Life of a Salmon in the Columbia River Basin." *NW Energy News*, June/July, 1986, pp. 13-16.
- Fisheries Association of British Columbia, et al. *Salmon: The Living Resource*. British Columbia, Canada, no date available.
- Harrison, George. "Journey of a Stream." *Sports Afield*, March, 1987, pp. 52-54.
- Knox, W.J., et al., *Spring Chinook Studies in the John Day River Salmon Studies*. Annual Report FY 1984, Portland: Oregon Department of Fish and Wildlife, Research and Development Section, December, 1984.
- Parmenter, Tish, and Robert Bailey. *The Oregon Oceanbook: An Introduction to the Pacific Ocean off Oregon Including its Physical Setting and Living Marine Resources*. Salem: Oregon Department of Land Conservation and Development, 1985.
- Province of British Columbia, Ministry of Environment. *Stream Enhancement Guide*. Vancouver, B.C., 1980.
- U.S. Department of the Interior. *Backgrounder*. Bonneville Power Administration, February, 1987.
- Yates, Steve. *Adopting A Stream: A Northwest Handbook*. Seattle: University of Washington Press, 1989.

Riffles and pools

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will analyze and describe how riffles and pools meet the needs of salmon and trout.

Method

Students will apply concepts learned about habitat needs of salmonids during their life cycle by completing a work sheet analyzing riffles and pools.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Requires some vocabulary building.

Materials

- copies of student sheets (pp. 361-364)

Background

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean,

Adapted from *Clean Water, Streams and Fish*, Borton, et al., pp. 123-125, 136-137.

and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams. Until they hatch, the cold (40°F to 65°F) water flowing through the gravel delivers oxygen and carries away wastes. The gravel itself protects the eggs from predators.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. They still depend on cold, well-oxygenated water for their survival and stay in the gravel for shelter. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Fry depend on streamside vegetation and the turbulent water at the beginning of pools for cover. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through **smoltification**, a physiological change, and are known as **smolts**. Smolting prepares them for life in saltwater. Once in the sea they spend up to five years, depending upon the species, feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream,

Vocabulary

alevins	milt
anadromous	redd
yolk sac	smoltification
fry	smolts

although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean.

Salmon spawning beds are generally found in the shallow headwaters of a stream and other suitable areas in the mainstems of streams. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky

substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Note: Trout, with the exception of steelhead and some cutthroat, are not anadromous. However, they are closely related to salmon and have needs similar to those of salmon during their time in fresh water.

Procedure

Now it's your turn . . .

Think about the last time you were at a stream. Let's review some of the things you might have observed or remember about good fish habitat.

- What is dissolved oxygen? Why is it important to streams and fish?
- What are pools? What are riffles? What kind of habitat do they provide for fish? Since salmonids spawn in gravel, and gravel is usually found in riffles, riffles are often called "spawning habitat." The amount of good quality gravel and riffles in a stream determine the number of salmonids that can spawn. The areas of a stream that provide places to eat, rest, and hide are called "rearing habitat."
- Stonefly and other aquatic insect larvae live on, around, and under rocks in the bottom of a stream. Some are shredders, feeding on decomposing leaves. Others are scrapers, grazing on algae growing on the rocks. Still others are predators that eat other invertebrates. To move to new rocks these aquatic insects detach themselves and drift downstream. Because they are carried by the current, most are found where the current is strongest. Salmonid fry eat these larvae (or floating sandwiches) as they drift past.

Look carefully at the drawings. Answer the questions based on your own experience and the introductory information in this exercise.

Questions

Refer to this diagram as you answer Questions 1 and 2.



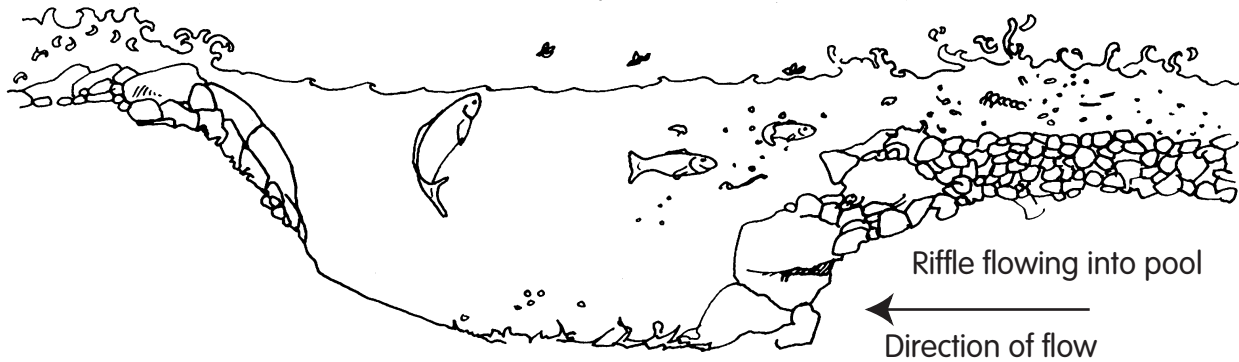
1. Will the dissolved oxygen concentration be higher at the bottom of the pools or in the riffles?

Generally, riffles should have more dissolved oxygen than pools, as a result of air and water mixing in the more turbulent water of the riffles.

2. Which would give more shelter or protection to salmonid eggs, pools or riffles? Why?

Riffles. The gravel usually found in the riffles would protect the eggs. Pools are more likely to have collections of fine sediments rather than gravels.

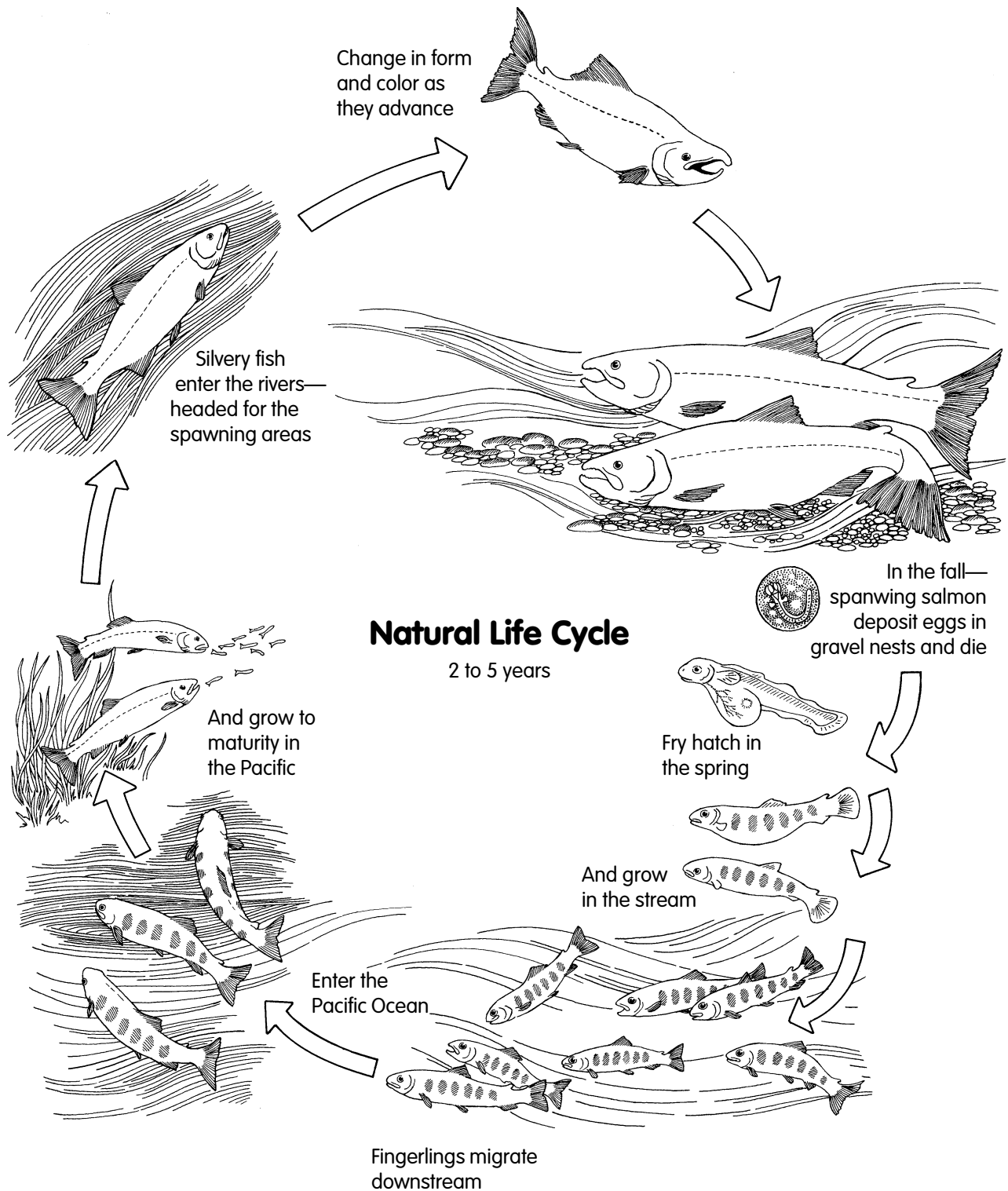
Refer to this diagram as you answer Questions 3 through 5.



3. What happens to aquatic insect larvae as the current enters a pool and slows down?
They settle to the bottom or are eaten by predators (other insects or fish).
4. Where would be the best place for salmonid fry to wait for lunch? Why?
At the head of a pool or tail of a riffle. To be first in line for drifting insects.
5. Where would salmonid fry use the most energy catching food? Why?
In the riffles. It is harder to maintain position in the faster water of a riffle.
6. Chum fry only spend as much time in the stream as it takes to get to the ocean (one day to three weeks). Coho salmon juveniles live for a year in the stream before heading to the ocean. Steelhead and sea-run cutthroat juveniles live up to three years in the stream before heading to the ocean. If a stream has good spawning habitat but not much rearing habitat, will it be more likely to support chum or coho salmon fry? Why?
Chum. Because chum salmon fry immediately begin moving toward the sea; they do not need extensive rearing habitat in the stream.
7. If a stream has both spawning and rearing habitat, which salmonid species might it support? Why?
Both. Coho salmon fry could live there because of the availability of rearing habitat.

Going further

1. Design an experiment to compare oxygen content of agitated and still water. Based on your results, hypothesize what the value of one might be over the other.
2. Design an experiment to measure the rate of flow in riffles and pools (and other habitats including glides, rapids, and cascades). Research the different types of fish habitat, including all kinds of slow and fast water habitats. Consult with a fish habitat biologist to learn how each of the habitat types provides for the needs of fish. Prepare a report or display of your findings and present to the class.
3. Contact your local department of fish and wildlife or watershed council. Volunteer to assist with fish habitat surveys on streams in your area. Ask local experts to train you in data collection methods and data analysis. Consider recruiting other volunteers to assist with the project. Prepare a report and share this information with the class.



Length of life cycle varies with species and consitions

Riffles and pools

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams. Until they hatch, the cold (40°F to 65°F) water flowing through the gravel delivers oxygen and carries away wastes. The gravel itself protects the eggs from predators.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. They still depend on cold, well-oxygenated water for their survival and stay in the gravel for shelter. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Fry depend on streamside vegetation and the turbulent water at the beginning of pools for cover. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through **smoltification**, a physiological change, and are known as **smolts**. Smolting prepares them for life in saltwater. Once in the sea they spend up to five years, depending upon the species, feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. No one knows for certain

Adapted from *Clean Water, Streams and Fish*, Borton, et al., pp. 123-125, 136-137.

how they find their way back to the same stream, although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean.

Salmon spawning beds are generally found in the shallow headwaters of a stream and other suitable areas in the mainstems of streams. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Note: Trout, with the exception of steelhead and some cutthroat, are not anadromous. However, they are closely related to salmon and have needs similar to those of salmon during their time in fresh water.

Now it's your turn . . .

Think about the last time you were at a stream. Let's review some of the things you might have observed or remember about good fish habitat.

- What is dissolved oxygen? Why is it important to streams and fish?

Vocabulary

alevins	milt
anadromous	redd
yolk sac	smoltification
fry	smolts

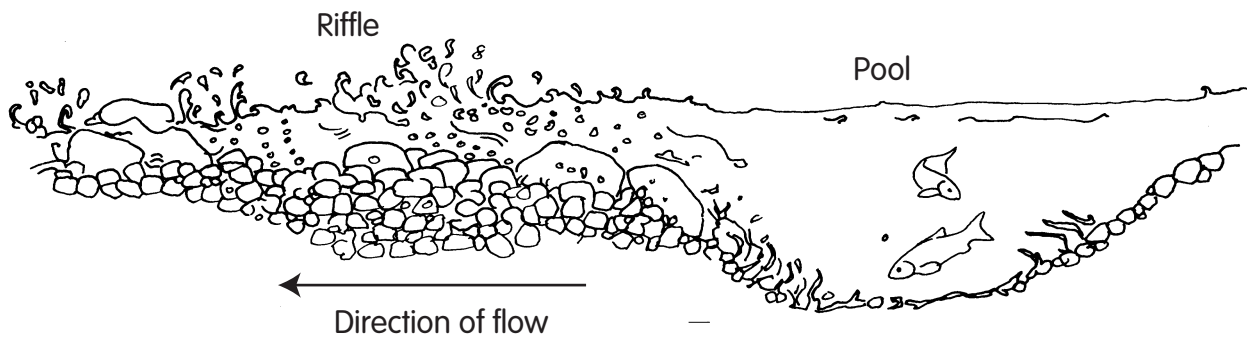
- What are pools? What are riffles? What kind of habitat do they provide for fish? Since salmonids spawn in gravel, and gravel is usually found in riffles, riffles are often called “spawning habitat.” The amount of good quality gravel and riffles in a stream determine the number of salmonids that can spawn. The areas of a stream that provide places to eat, rest, and hide are called “rearing habitat.”
- Stonefly and other aquatic insect larvae live on, around, and under rocks in the bottom of a stream. Some are shredders, feeding on decomposing leaves. Others are scrapers, grazing on

algae growing on the rocks. Still others are predators that eat other invertebrates. To move to new rocks these aquatic insects detach themselves and drift downstream. Because they are carried by the current, most are found where the current is strongest. Salmonid fry eat these larvae (or floating sandwiches) as they drift past.

Look carefully at the drawings. Answer the questions based on your own experience and the introductory information in this exercise.

Questions

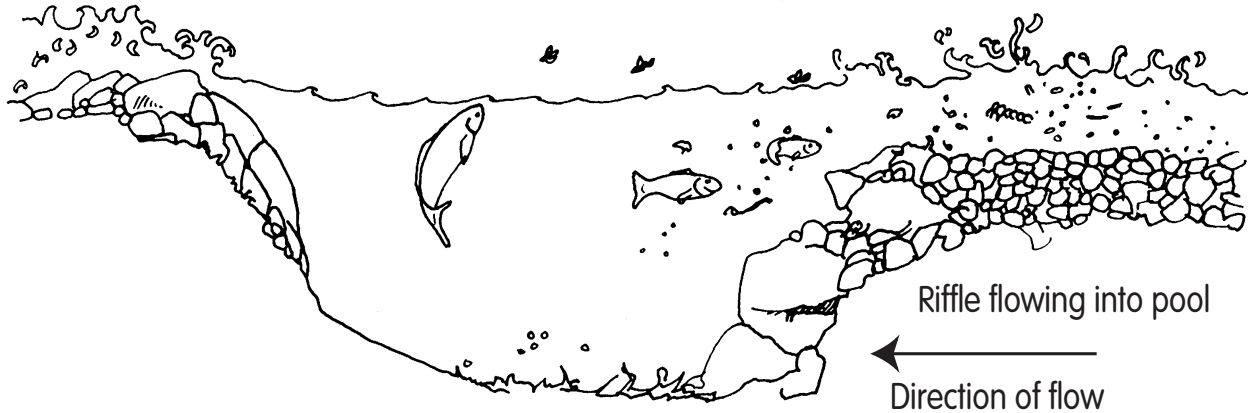
Refer to this diagram as you answer Questions 1 and 2.



1. Will the dissolved oxygen concentration be higher at the bottom of the pools or in the riffles?
2. Which would give more shelter or protection to salmonid eggs, pools or riffles? Why?

Student sheet

Refer to this diagram as you answer Questions 3 through 5.



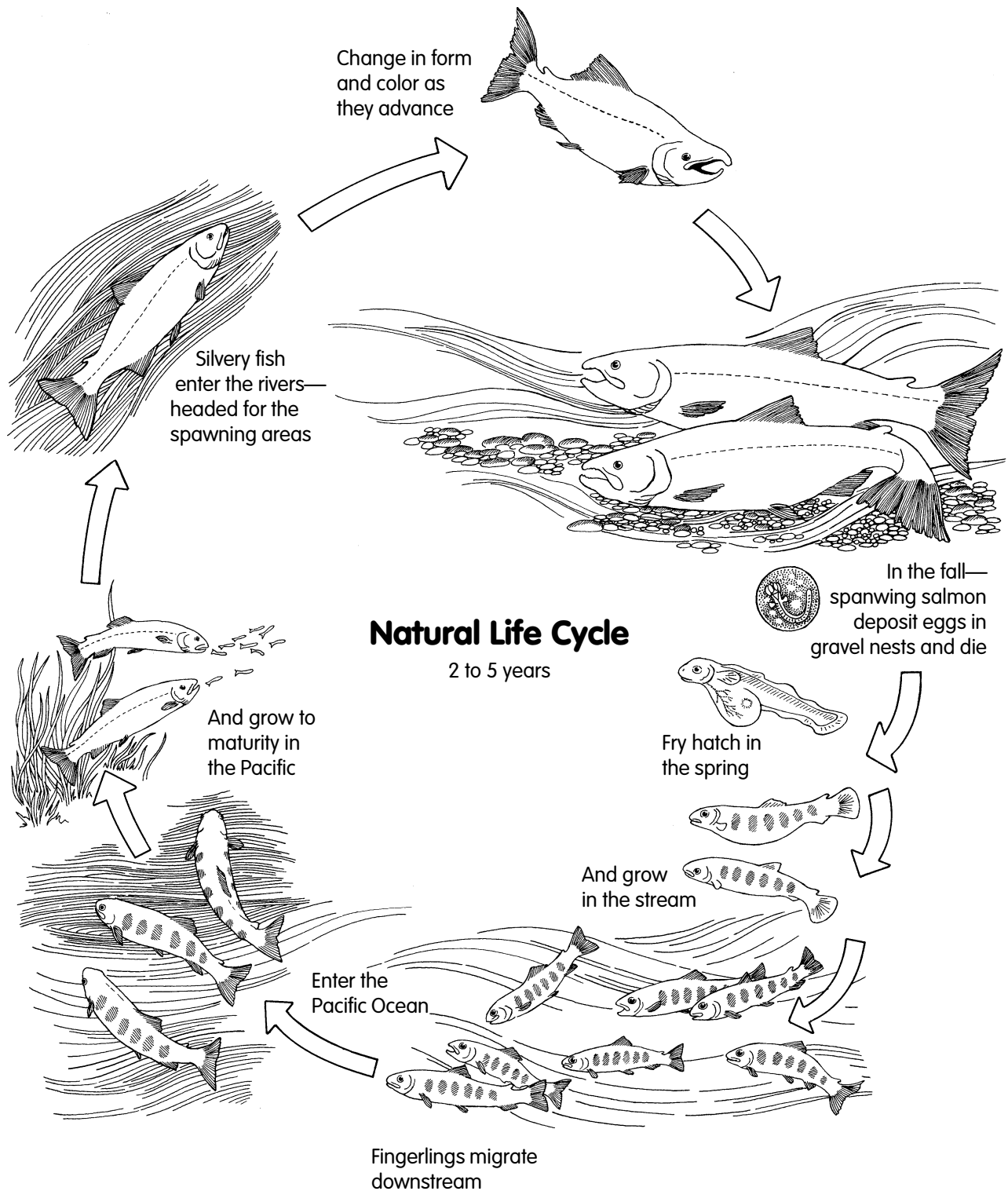
3. What happens to aquatic insect larvae as the current enters a pool and slows down?

4. Where would be the best place for salmonid fry to wait for lunch? Why?

5. Where would salmonid fry use the most energy catching food? Why?

6. Chum fry only spend as much time in the stream as it takes them to get to the ocean (one day to three weeks). Coho salmon juveniles live for a year in the stream before heading to the ocean. Steelhead and sea-run cutthroat juveniles live up to three years in the stream before heading to the ocean. If a stream has good spawning habitat but not much rearing habitat, will it be more likely to support chum or coho salmon fry? Why?

7. If a stream has both spawning and rearing habitat, which salmonid species might it support? Why?



Length of life cycle varies with species and consitions

Student sheet

Salmon language crossword puzzle

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will demonstrate understanding of the basic concepts of the salmon life cycle by completing the crossword puzzle.

Method

Students will complete the crossword puzzle, with or without the accompanying word list at the teacher's discretion.

For younger students

1. In most cases, younger students will require the word list. Using an overhead transparency of the salmon life cycle while discussing the important concepts as a group may enhance this exercise.
2. Work in pairs or as a group to solve the puzzle. Add the "Going Further" activities to help younger students grasp the concepts.

Materials

- crossword puzzle (pp. 369-371), list of clues, and word list (optional)

Background

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Aquatic invertebrates provide most of the food for salmon fry.

When they are ready to migrate to the sea, they go through a physiological change and are known as **smolts**. Once in the sea some spend up to five years feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Procedure

Now it's your turn . . .

Do you understand how the salmon life cycle fits into the "watershed" picture? Can you name and describe the major steps of the salmon life cycle? Use the following crossword puzzle to test your knowledge about the salmon life cycle and to practice the new words you have learned.

Salmon Language Crossword Clues

Across

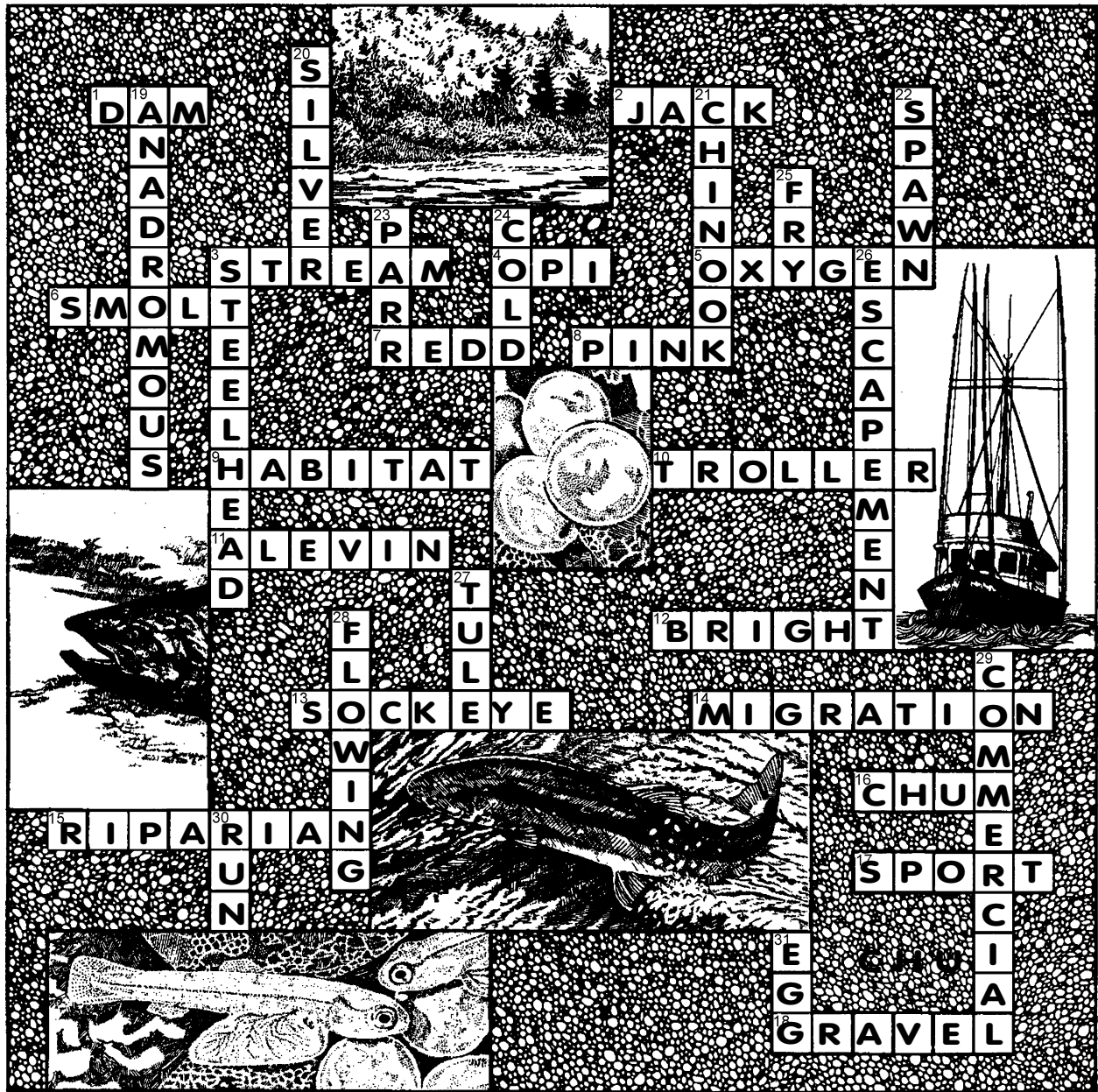
1. A major barrier to the migration of salmon and steelhead.
2. Early maturing, two-year-old coho (silver) salmon that return to spawn a year earlier than normal.
3. A healthy _____ is required to produce healthy juvenile chinook and coho salmon.
4. Abbreviation for Oregon Production Index, a mathematical model used to predict the size of runs of coho salmon (based on the return of two-year-old jack salmon).
5. Salmon eggs, juveniles, and adults must have _____ dissolved in the water to survive.
6. A juvenile salmon that is ready to migrate to sea is called a _____.
7. A salmon nest where eggs are deposited.
8. The shortest-lived and smallest of the Pacific salmon. The males develop a large humpback during spawning.
9. For salmon, cold water, plenty of food and good cover is excellent _____.
10. The term for commercial fishing boats and fishermen that fish for ocean salmon.
11. A newly hatched salmon with the unabsorbed yolk sac still attached.
12. Upper Columbia and Snake River fall spawning chinook salmon stocks which enter the river in excellent condition.
13. Species of salmon that usually spawn in streams having lakes in their watershed and are related to kokanee.
14. The _____ of the salmon has puzzled humans for centuries.
15. Healthy streambanks, called _____ zones, are essential for good natural salmon production.
16. Another name for dog salmon.
17. When salmon are caught for recreation and personal use, it is called _____ fishing.
18. Good spawning sites always have _____ for salmon to build redds in.

Down

3. A rainbow trout that spends much of its life in the ocean.
19. Fish that migrate from the sea to spawn in fresh water are called _____ fishes.
20. Another name for the coho salmon.
21. The largest salmon, also called a “king.”
22. Term used to describe the laying of eggs by the female salmon and their fertilization by the male.
23. An older juvenile salmon with dark, oblong bars along each side is called a _____.
24. Water in which salmon live must be fairly _____.
25. Salmon that have absorbed their yolk sacs, emerged from the gravel, and are ready to feed.
26. Those salmon that are *not* caught by commercial or sport fisheries and escape to spawn in streams or hatcheries.
27. A stock of chinook salmon used in many lower Columbia River hatcheries.
28. _____ water is required around salmon eggs to deliver oxygen and carry away waste products.
29. When fish are caught and sold for profit, it is called _____ fishing.
30. The salmon entering a river system during a specific time of year are called that river’s _____.
31. The _____ to fry stage in the salmon’s life cycle is the period of greatest mortality.

Going further

1. After working the crossword puzzle, alphabetize all the words.
2. Write one complete sentence using each word in the crossword puzzle



Word list

alevin	cold	flowing	migration	redd	sockeye	troller
anadromous	commercial	fry	OPI	riparian	spawn	tule
bright	dam	gravel	oxygen	run	sport	
chinook	egg	habitat	parr	silver	steelhead	
chum	escapement	jack	pink	smolt	stream	

Salmon language crossword puzzle

Do you know . . .

All Pacific salmon are **anadromous**. They begin their lives in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Salmon are important to Oregon's commercial and recreational fisheries.

The salmon life cycle begins when eggs are deposited and fertilized in the gravel of cool, clean rivers and streams.

In late winter or spring, the eggs hatch. The young fish, called **alevins**, are less than one inch long. During this time they are fed from a **yolk sac** that protrudes from their bellies. As the yolk sacs are used up, the fish, now called **fry**, emerge from the gravel in late spring or summer, approximately one to three months after hatching.

The fry of some species head directly for the sea, but others might stay in freshwater for a few months to a few years. Aquatic invertebrates provide most of the food for salmon fry.

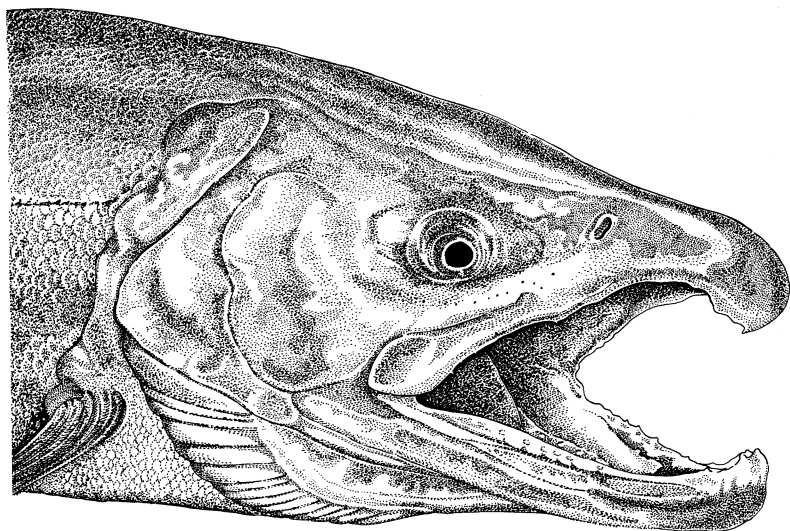
When they are ready to migrate to the sea, they go through a physiological change and are known as **smolts**. Once in the sea some spend up

to five years feeding and growing before they are ready to return to fresh water.

Salmon return to spawn in the same stream where they hatched. Weeks or months after they have reached the gravel beds, the female digs a nest, or **redd**. Here she deposits up to 5,000 eggs. The male fertilizes the eggs by covering them with **milt**, a milky substance that contains the sperm. The female finishes the spawning process by covering the eggs with gravel. After spawning, the salmon's life is finished. Within a short time, it dies and the carcass drifts downstream, decaying and contributing its nutrients to the stream from which it originally came.

Now it's your turn . . .

Do you understand how the salmon life cycle fits into the "watershed" picture? Can you name and describe the major steps of the salmon life cycle? Use the following crossword puzzle to test your knowledge about the salmon life cycle and to practice the new words you have learned.



Salmon Language Crossword Clues

Across

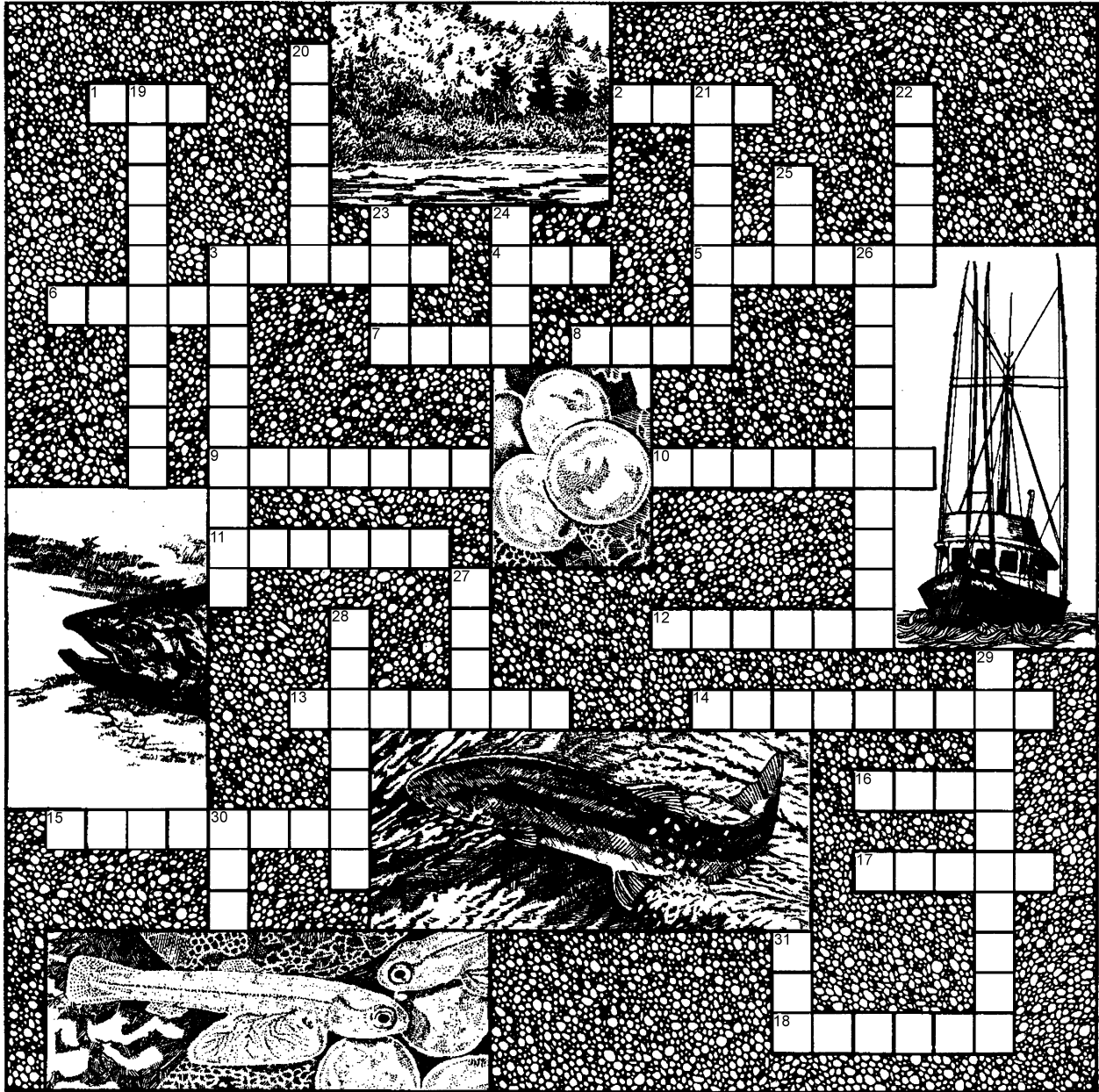
1. A major barrier to the migration of salmon and steelhead.
2. Early maturing, two-year-old coho (silver) salmon that return to spawn a year earlier than normal.
3. A healthy _____ is required to produce healthy juvenile chinook and coho salmon.
4. Abbreviation for Oregon Production Index, a mathematical model used to predict the size of runs of coho salmon (based on the return of two-year-old jack salmon).
5. Salmon eggs, juveniles, and adults must have _____ dissolved in the water to survive.
6. A juvenile salmon that is ready to migrate to sea is called a _____.
7. A salmon nest where eggs are deposited.
8. The shortest-lived and smallest of the Pacific salmon. The males develop a large humpback during spawning.
9. For salmon, cold water, plenty of food and good cover is excellent _____.
10. The term for commercial fishing boats and fishermen that fish for ocean salmon.
11. A newly hatched salmon with the unabsorbed yolk sac still attached.
12. Upper Columbia and Snake River fall spawning chinook salmon stocks which enter the river in excellent condition.
13. Species of salmon that usually spawn in streams having lakes in their watershed and are related to kokanee.
14. The _____ of the salmon has puzzled humans for centuries.
15. Healthy streambanks, called _____ zones, are essential for good natural salmon production.
16. Another name for dog salmon.

17. When salmon are caught for recreation and personal use, it is called _____ fishing.
18. Good spawning sites always have _____ for salmon to build redds in.

Down

3. A rainbow trout that spends much of its life in the ocean.
19. Fish that migrate from the sea to spawn in fresh water are called _____ fishes.
20. Another name for the coho salmon.
21. The largest salmon, also called a “king.”
22. Term used to describe the laying of eggs by the female salmon and their fertilization by the male.
23. An older juvenile salmon with dark, oblong bars along each side is called a _____.
24. Water in which salmon live must be fairly _____.
25. Salmon that have absorbed their yolk sacs, emerged from the gravel, and are ready to feed.
26. Those salmon that are *not* caught by commercial or sport fisheries and escape to spawn in streams or hatcheries.
27. A stock of chinook salmon used in many lower Columbia River hatcheries.
28. _____ water is required around salmon eggs to deliver oxygen and carry away waste products.
29. When fish are caught and sold for profit, it is called _____ fishing.
30. The salmon entering a river system during a specific time of year are called that river’s _____.
31. The _____ to fry stage in the salmon’s life cycle is the period of greatest mortality.

Student sheet



Word list

gravel	cold	run	stream	redd	bright	jack
sockeye	anadromous	escapement	migration	smolt	commercial	dam
alevin	OPI	habitat	egg	spawn	fry	
flowing	sport	parr	tule	steelhead	chinook	
pink	riparian	oxygen	troller	chum	silver	

Student sheet

Student sheet

Coming home!

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

Students will (1) identify a diversity of issues affecting watersheds and salmonid populations within those watersheds, (2) create an advertising campaign designed to encourage salmonids to return to their home stream, and (3) critique and score other teams' work to assess student understanding of key watershed and fish habitat concepts.

Method

Students will investigate, write, and produce an advertising campaign, in a poster format, that features reasons for salmonids to migrate to a specific stream to spawn.

For younger students

1. To initiate the activity use examples of advertising campaigns found in children's magazines rather than those for older children and adults.
2. Modify the requirements so younger students prepare their advertising campaign on butcher paper that can be displayed on room or hall-

This activity is adapted from "Salmon Stream Advertisement" created by Patrick Griffiths, Pilot Butte Middle School, 1500 NE Penn, Bend, Oregon 97701, and used with permission. Portions of the activity content are adapted from *Small Streams*, a Salmonid Enhancement Program fact sheet, Department of Fisheries and Oceans, BC Ministry of Environment, 555 West Hastings Street, Vancouver, B.C. Canada V6B5G3.

way walls. Assign different parts of the campaign to different groups of students rather than each group completing the entire campaign.

3. Review key vocabulary and components of good fish habitat with students before starting the activity.

Materials

- writing materials
- colored and white paper
- 24"×36" poster board or foam core board
- markers, color pencils, paints, crayons, and other art supplies
- computer/printer (optional)
- copies of student pages 381-386

Notes to the teacher

This activity is designed as the concluding exercise of a watershed, water quality and fish habitat unit. The activity incorporates an array of skills that include art ability, graphic sense, design capabilities, creative writing, composition, research, group process, and decision making to assess student understanding and retention of key concepts about watersheds, water quality, and fish habitat. Collaborate with instructors in other curriculum areas (art, English, journalism, careers) so students understand that the study of watersheds is not limited to science.

Although it is a generally accepted fact that most salmon return to the same stream in which they were spawned, some straying to nearby streams does occur. Straying, to some extent, has been responsible for reestablishment of fish populations in streams following catastrophic natural events. Historically, straying has also provided opportunities for the exchange of genetic resources among nearby populations, thus increasing the genetic diversity of the species.

Take the time to go over these general facts with your students prior to beginning the activity. Although not using the subject of straying directly, for the purposes of this exercise, students will use the concept of good habitat to “lure” a salmon to come to their stream to spawn rather than returning to the stream of their birth.

Background

Do you know . . .

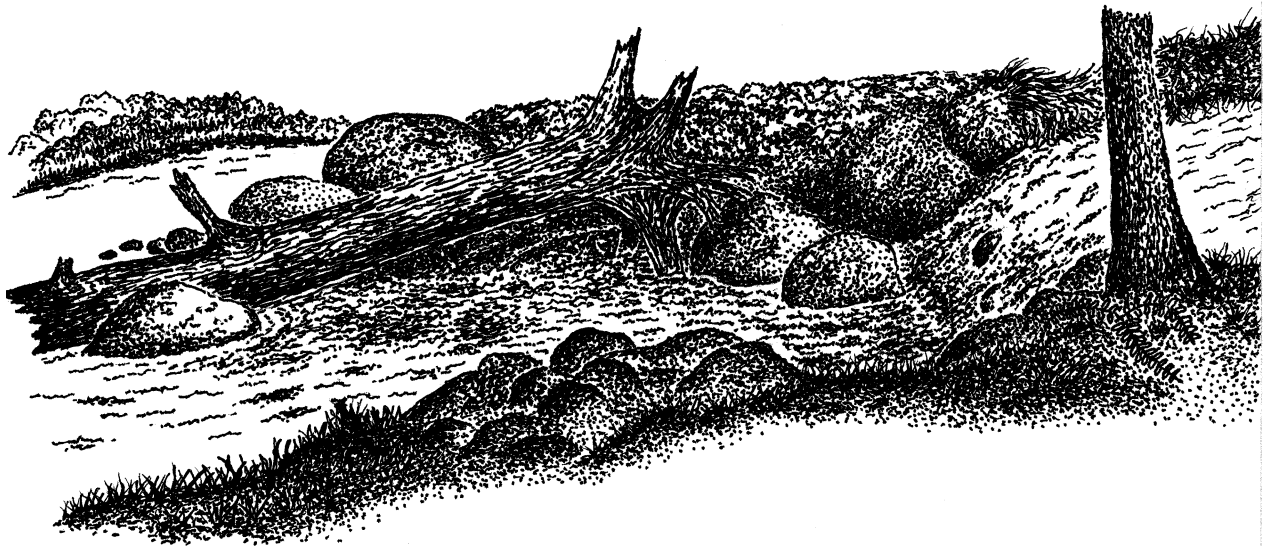
Most clean, healthy streams, no matter how small, can contribute to salmonid (salmon and trout) habitat. All salmonids—salmon, steelhead, and trout—spend at least a part of their life cycle in small streams. Some, like chum or pink salmon, may only spend a few weeks in the stream or the estuary before moving to the ocean, while others may spend three or more years before migrating. Young sockeye salmon move from small streams to rear in freshwater lakes for one or more years while still other species are permanent residents of large and small streams.

A single stream may appear insignificant as a producer of wild fish. But together, thousands of small streams throughout the Northwest account for a lot of fish production. Healthy streams are valuable, but they are fragile. They are easily damaged by poor agriculture and forestry practices, pollution, mining, and urban development.

Wild salmonids need certain stream conditions to survive. Salmonids need clean water for every stage of their life cycle. A healthy stream usually runs cool and clear over a clean gravel bottom. The silt present in cloudy water can coat incubating eggs and surrounding gravel, preventing oxygen from reaching the eggs. Without oxygen the eggs will die. In a healthy, natural stream, the flow of clean water usually remains steady. The land on both sides of a healthy stream acts as a giant sponge to soak up heavy rains. This water is then released slowly into the stream. Slow release of groundwater also prevents small streams from drying up during the warm summer months.

Aquatic organisms, including fish, have a relatively narrow temperature range for survival. Shade provided by trees and other plants that grow beside the stream helps keep the water cool and within that acceptable range. Insects that feed on the leaves and branches of these stream-side plants sometimes fall into the water providing food for the fish. Mayflies and other insects that land on the water’s surface to lay their eggs are also eaten by fish. Some insect eggs hatch and become part of the stream food chain. These aquatic forms of insects live on, around, and among the rocks of the streambed. These insect forms are often carried along by the water current where they become part of the menu for a fish waiting downstream.

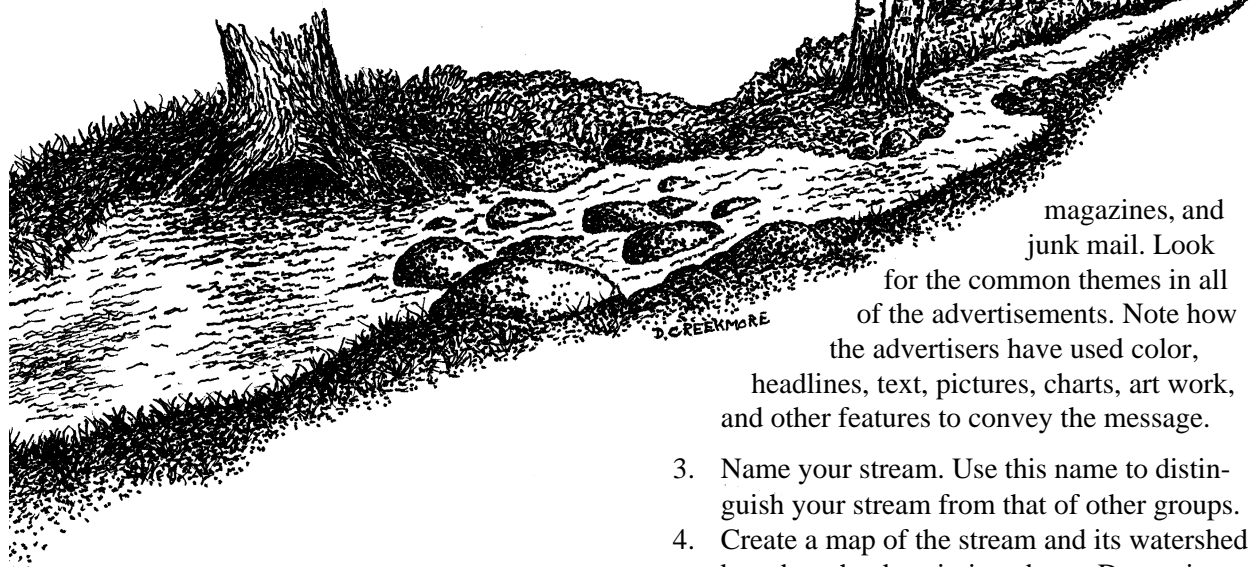
Small streams often contain natural debris such as root wads, fallen trees,



and boulders. Fish use these structures to hide from their enemies which include larger fish, birds, and small animals.

Adult migratory salmonids, like salmon and steelhead, need a barrier-free route to their spawning areas. They also need cover, both in the stream and alongside it, for protection from predators and for shaded resting areas. Salmon usually return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream, although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean. Within days of spawning, adult salmon die, contributing the nutrients in their bodies to the stream from which it originally came.

Once young fish hatch they also need barrier-free access as they distribute themselves both upstream and downstream where food and cover is available.



Procedure

Now it's your turn . . .

You are an employee of an advertising firm that has been hired by the local watershed council. A local client has approached the watershed council for help in getting salmon to come back to the

stream on his property. The stream begins in a wilderness headwater area, flows through farmland and finally through urban areas on its way to the Pacific Ocean. This stream needs salmon!

You are going to break with tradition and see if you can get salmon to come back to this stream even though they did not originally grow up there. Your job is to create an advertisement that will attract salmon to this stream! The advertisement will tell salmon how great the stream is and why it is suitable place for salmon to live.

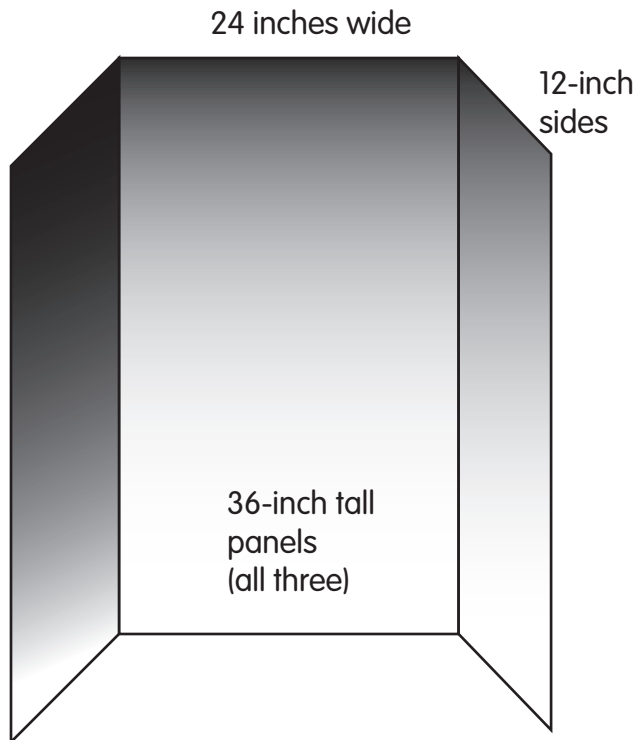
The ultimate goal of the advertisement is to communicate what salmon need to live and reproduce, impacts human activities have had on watersheds in the past, and how we can improve streams to attract salmon in the future.

1. Work in groups of three students.
2. As a group, look at examples of advertising campaigns in newspapers, a variety of

magazines, and junk mail. Look for the common themes in all of the advertisements. Note how the advertisers have used color, headlines, text, pictures, charts, art work, and other features to convey the message.

3. Name your stream. Use this name to distinguish your stream from that of other groups.
4. Create a map of the stream and its watershed based on the description above. Determine where in the watershed the client wants salmon to spawn? Center your work in that area.
5. Organize your thoughts around the question "Why should salmon come and live in this stream?"

6. Create a planning guide around the main topics noted below. Use the questions following each topic to prepare for the advertising campaign and guide your research. Then, choose the points you want to emphasize in the advertisement.
 - **pH:** what is it, why is it important, how have humans altered the pH of streams, what range do salmon like best, how can humans keep pH within acceptable ranges.
 - **Temperature:** why are cool temperatures important to fish, how have human actions changed water temperatures in rivers and streams, what is the best temperature range for salmon, how can you protect a stream against drastic changes in temperature.
 - **Dissolved oxygen:** what is dissolved oxygen, why is it important to fish and other organisms, how do dissolved oxygen concentrations change naturally, how do human activities change dissolved oxygen concentrations (for worse or better) in streams, how is dissolved oxygen related to temperature, what are the best levels for salmon, and do salmon need different amounts of dissolved oxygen during different parts of their life cycle.
 - **Sediment:** what is sediment, what is its source, what is its effect on a stream (good and bad), how are excessive sediment accumulations controlled.
 - **Food:** what are the food needs for salmonids, how does the stream provide for these needs.
 - **Stream habitat:** what are the physical habitat requirements of a stream that will meet the needs of various stages of a salmon's life cycle, how will your stream keep sediment in check.
 - **Pollutants:** how might fertilizers, pesticides, or other pollutants get into a stream and how might they harm a river or stream, how are pollutant problems solved.
 - **Watershed land use activities:** how might watershed activities like mining, forestry, ranching, and farming practices, commercial and recreational fishing, dams, and urban development affect rivers and streams and salmon (good and bad), what are some alternatives, how can watershed management activities be designed to be salmon-friendly
 - **What does a healthy stream look like:** in the forest, passing through a farm, passing through a city?
7. Use butcher paper or other large pieces of paper to prepare a rough draft of the advertisement. Consider the following as you plan the display.
 - What key information will you include?
 - Where will you place the key information on the poster?
 - What colors will you use?
 - Who is your audience?
 - What are you trying to sell?
 - What graphics, pictures, or artwork will you use?
 - Will you include a map or picture of your stream to help illustrate your ideas or solutions?
 - Will you use cut-away drawings or tables and charts?
 - Will you use handwritten or typed headings? What will the headings say?
 - Will you use handwritten or typed blocks of text?
 - Will you add 3-D models? Hanging or attached?
 - Will you use interactive parts (flip cards with answers or facts) on the display?
8. Prepare the final advertisement as a tri-fold poster made from two pieces of 24"×36" poster board or ¼" foam core board. See diagram.
9. A successful project will include:
 - The stream name in a prominent location.
 - Appropriate stream, fish and watershed words.
 - Effective layout and promotional features, (quotes from visitors, headlines, etc.).



- Pictures, diagrams, artwork, and photographs to help tell the story.
 - Well-organized information so that the message and the effect is clear and attractive.
 - Specific methods used to improve past stream habitat problems.
10. Set up your advertisement for display. Obtain a copy of the grading sheet. Write the name of your stream in the box provided. List group member's names on the back of the grading sheet. Place the grading sheet in a location close to your advertisement. Move around the room viewing the advertisements produced by other groups. Choose two, other than your own, to score. As a group complete the grading sheet for each advertisement you have chosen. When four different groups have scored your advertisement, turn in the grading sheet to the teacher.
11. Answer the following questions.

Stream Name _____

Grading Sheet: Coming Home

Points Possible: 20 out of 20 or 10 out of 10 is a perfect score. There are very few perfect projects

Category Description	Points possible: Group # >	Grader Group #	Grader Group #	Grader Group #	Grader Group #	Teacher Grade
Followed directions: see instructions: size, shape, format.	20					
Appropriate words: examples connected to lessons	20					
Is the advertisement easy to read? Does it help "sell" the stream. Does it make you want to go there?	20					
Is the advertisement clear and attractive?	20					
Do pictures, diagrams or other graphics help the advertisement without confusing the message?	10					
Are improvement methods shown? (for making or keeping the stream in good shape?)	10					
Is specific information included about watershed activities? Is the information accurate?	10					
Is specific information included about physical habitat requirements? Is it accurate?	10					
Total	120					
Grader's Group #	What did you like best about this advertisement?		Were any items missing from this advertisement? Any other suggestions?			

Questions

1. What did you like most about this activity? What did you like least? Why?
Answers will vary.
2. How did this activity help you complete your study of watersheds and fish habitat?
Answers will vary, but should include some thoughts to show an understanding that all parts of a watershed are connected and that what happens in the upper part of a watershed affects what is going on downstream. Students should recognize that healthy fish habitat must meet the four basic needs—food, water, shelter, and space.
3. What would you change if you were to do this activity again? Why?
Answers will vary.
4. What were the main sources of information used to complete your research?
Answers will vary.
5. What was the most interesting thing you learned about advertising as a means of persuasion?
Answers will vary.

Going further

1. Convert the advertisement idea to a newspaper format. Use the ideas in “Aquatic Times,” *Aquatic Project WILD* pp. 126-128 to set up the activity. Assign students to write newspaper articles about different parts of procedure 6 above, then arrange them in a newspaper format. Ask staff from the school newspaper to give a presentation about the key features of a newspaper.
2. Ask students with an interest in art to create appropriate graphics for illustrating key components of this activity. Contact the local fish and wildlife agency or other natural resource agency to see if they are interested in artwork for their programs.
3. Arrange for a “salmon fair” or other event to spotlight the needs of salmon. Ask groups to volunteer to share their advertising displays and to prepare a verbal presentation about what they have learned as a result of the activity.

Coming home!

Do you know . . .

Most clean, healthy streams, no matter how small, can contribute to salmonid (salmon and trout) habitat. All salmonids—salmon, steelhead, and trout—spend at least a part of their life cycle in small streams. Some, like chum or pink salmon, may only spend a few weeks in the stream or the estuary before moving to the ocean, while others may spend three or more years before migrating. Young sockeye salmon move from small streams to rear in freshwater lakes for one or more years while still other species are permanent residents of large and small streams.

A single stream may appear insignificant as a producer of wild fish. But together, thousands of small streams throughout the Northwest account for a lot of fish production. Healthy streams are valuable, but they are fragile. They are easily damaged by poor agriculture and forestry practices, pollution, mining, and urban development.

Wild salmonids need certain stream conditions to survive. Salmonids need clean water for every stage of their life cycle. A healthy stream usually runs cool and clear over a clean gravel bottom. The silt present in cloudy water can coat incubating eggs and surrounding gravel, preventing oxygen from reaching the eggs. Without oxygen the eggs will die. In a healthy, natural stream, the flow of clean water usually remains steady. The land on both sides of a healthy

stream acts as a giant sponge to soak up heavy rains. This water is then released slowly into the stream. Slow release of groundwater also prevents small streams from drying up during the warm summer months.

Aquatic organisms, including fish, have a relatively narrow temperature range for survival. Shade provided by trees and other plants that grow beside the stream helps keep the water cool and within that acceptable range. Insects that feed on the leaves and branches of these stream-side plants sometimes fall into the water providing food for the fish. Mayflies and other insects that land on the water's surface to lay their eggs are also eaten by fish. Some insect eggs hatch and become part of the stream food chain. These aquatic forms of insects live on, around, and among the rocks of the streambed. These insect forms are often carried along by the water current where they become part of the menu for a fish waiting downstream.

Small streams often contain natural debris such as root wads, fallen trees, and boulders. Fish use these structures to hide from their enemies which include larger fish, birds, and small animals.

Adult migratory salmonids, like salmon and steelhead, need a barrier-free route to their spawning areas. They also need cover, both in the stream and alongside it, for protection from predators and for shaded resting areas. Salmon usually return to spawn in the same stream where they hatched. No one knows for certain how they find their way back to the same stream, although one theory is that they can smell or actually taste the water chemistry of their home stream. When they enter fresh water, salmon stop feeding. Their journey upriver is made on the energy stored while living in the ocean. Within days of spawning, adult salmon die, contributing the nutrients in their bodies to the stream from which it originally came.

This activity is adapted from "Salmon Stream Advertisement" created by Patrick Griffiths, Pilot Butte Middle School, 1500 NE Penn, Bend, Oregon 97701, and used with permission. Portions of the activity content are adapted from *Small Streams*, a Salmonid Enhancement Program fact sheet, Department of Fisheries and Oceans, BC Ministry of Environment, 555 West Hastings Street, Vancouver, B.C. Canada V6B5G3.

Once young fish hatch they also need barrier-free access as they distribute themselves both upstream and downstream where food and cover is available.

Now it's your turn . . .

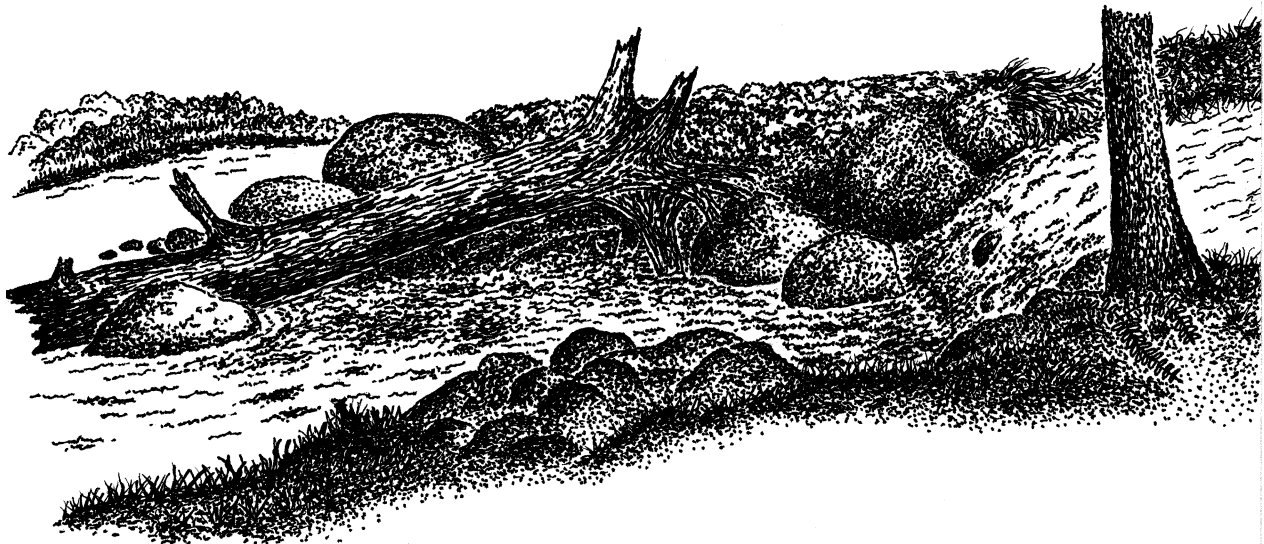
You are an employee of an advertising firm that has been hired by the local watershed council. A local client has approached the watershed council for help in getting salmon to come back to the stream on his property. The stream begins in a wilderness headwater area, flows through farmland and finally through urban areas on its way to the Pacific Ocean. This stream needs salmon! You are going to break with tradition and see if you can get salmon to come back to this stream even though they did not originally grow up there. Your job is to create an advertisement that will attract salmon to this stream! The advertisement will tell salmon how great the stream is and why it is suitable place for salmon to live.

The ultimate goal of the advertisement is to communicate what salmon need to live and reproduce, impacts human activities have had on watersheds in the past, and how we can improve streams to attract salmon in the future.

1. Work in groups of three students.
2. As a group, look at examples of advertising campaigns in newspapers, a variety of magazines, and junk mail. Look for the common themes in all of the advertisements. Note how the advertisers have used color,

headlines, text, pictures, charts, art work, and other features to convey the message.

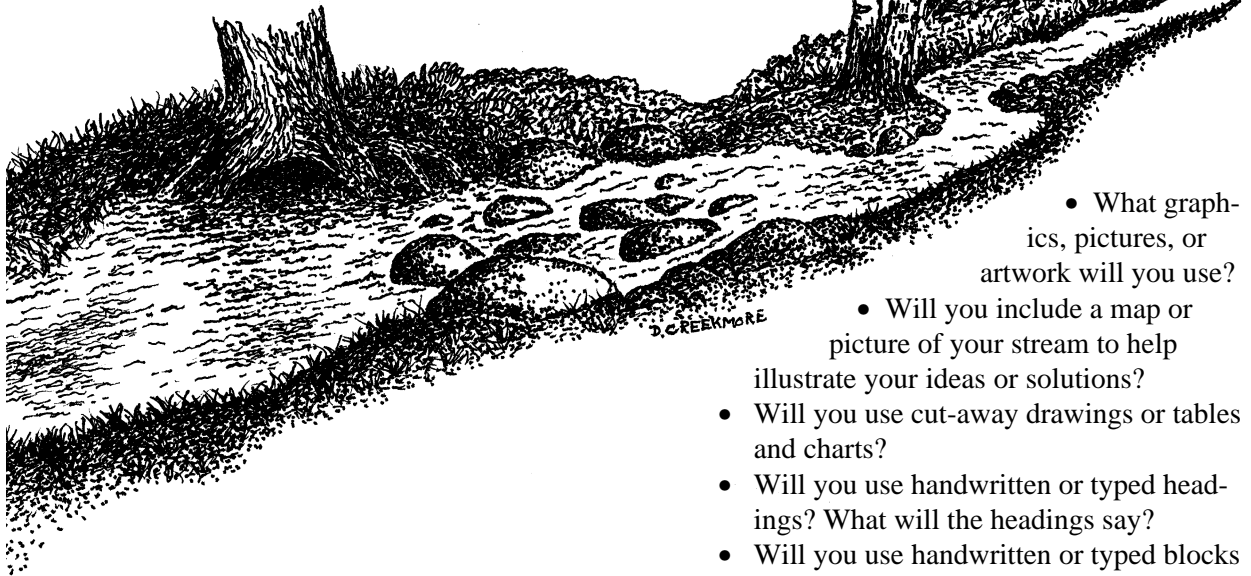
3. Name your stream. Use this name to distinguish your stream from that of other groups.
4. Create a map of the stream and its watershed based on the description above. Determine where in the watershed the client wants salmon to spawn? Center your work in that area.
5. Organize your thoughts around the question "Why should salmon come and live in this stream?"
6. Create a planning guide around the main topics noted below. Use the questions following each topic to prepare for the advertising campaign and guide your research. Then, choose the points you want to emphasize in the advertisement.
 - **pH:** what is it, why is it important, how have humans altered the pH of streams, what range do salmon like best, how can humans keep pH within acceptable ranges.
 - **Temperature:** why are cool temperatures important to fish, how have human actions changed water temperatures in rivers and streams, what is the best temperature range for salmon, how can you protect a stream against drastic changes in temperature.
 - **Dissolved oxygen:** what is dissolved oxygen, why is it important to fish and



Student sheef

other organisms, how do dissolved oxygen concentrations change naturally, how do human activities change dissolved oxygen concentrations (for worse or better) in streams, how is dissolved oxygen related to temperature, what are the best levels for salmon, and do salmon need different amounts of dissolved oxygen during different parts of their life cycle.

- **Sediment:** what is sediment, what is its source, what is its effect on a stream (good and bad), how are excessive sediment accumulations controlled.
- **Food:** what are the food needs for salmonids, how does the stream provide for these needs.
- **Stream habitat:** what are the physical habitat requirements of a stream that will meet the needs of various stages of a salmon's life cycle, how will your stream keep sediment in check.



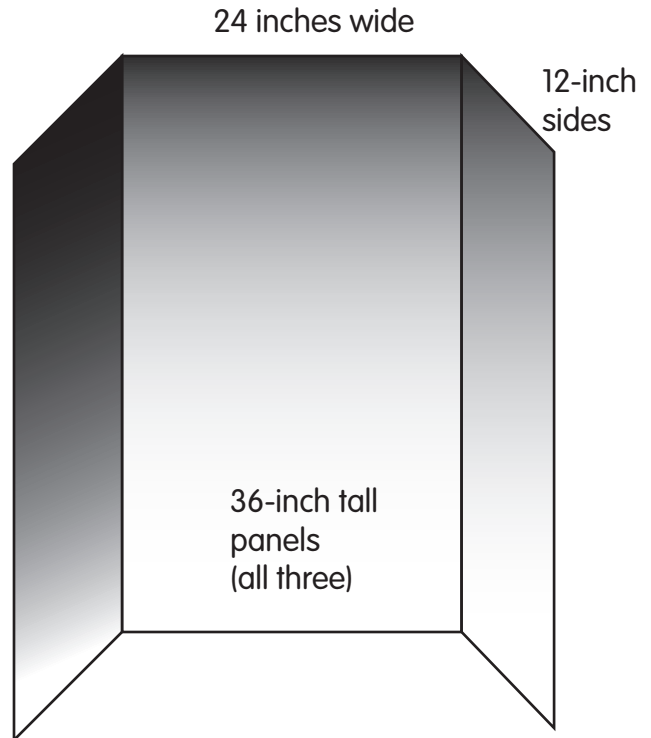
- **Pollutants:** how might fertilizers, pesticides, or other pollutants get into a stream and how might they harm a river or stream, how are pollutant problems solved.
- **Watershed land use activities:** how might watershed activities like mining, forestry, ranching, and farming practices,

commercial and recreational fishing, dams, and urban development affect rivers and streams and salmon (good and bad), what are some alternatives, how can watershed management activities be designed to be salmon-friendly

- **What does a healthy stream look like:** in the forest, passing through a farm, passing through a city?
7. Use butcher paper or other large pieces of paper to prepare a rough draft of the advertisement. Consider the following as you plan the display.
 - What key information will you include?
 - Where will you place the key information on the poster?
 - What colors will you use?
 - Who is your audience?
 - What are you trying to sell?

- What graphics, pictures, or artwork will you use?
 - Will you include a map or picture of your stream to help illustrate your ideas or solutions?
8. Prepare the final advertisement as a tri-fold poster made from two pieces of 24"×36" poster board or 1/4" foam core board. See diagram.

9. A successful project will include:
- The stream name in a prominent location.
 - Appropriate stream, fish and watershed words.
 - Effective layout and promotional features, (quotes from visitors, headlines, etc.).
 - Pictures, diagrams, artwork, and photographs to help tell the story.
 - Well-organized information so that the message and the effect is clear and attractive.
 - Specific methods used to improve past stream habitat problems.
10. Set up your advertisement for display. Obtain a copy of the grading sheet. Write the name of your stream in the box provided. List group member's names on the back of the grading sheet. Place the grading sheet in a location close to your advertisement. Move around the room viewing the advertisements produced by other groups. Choose two, other than your own, to score. As a group complete the grading sheet for each advertisement you have chosen. When four different groups have scored your advertisement, turn in the grading sheet to the teacher.
11. Answer the following questions.



Student sheet

Questions

1. What did you like most about this activity? What did you like least? Why?
2. How did this activity help you complete your study of watersheds and fish habitat?
3. What would you change if you were to do this activity again? Why?
4. What were the main sources of information used to complete your research?
5. What was the most interesting thing you learned about advertising as a means of persuasion?

Student sheet

Fish habitat needs

9.3

"The falling waters led me, the foodful waters fed me."
— Ralph Waldo Emerson

Though the physical characteristics of a stream largely determine its ability to produce fish, survival of each new hatch is dependent upon many environmental factors. A relatively stable, pollutant-free water flow is important for a productive stream.

Anadromous salmonids use a variety of streams. Although each species has its own specific habitat requirements, some generalizations can be made.

Spawning habitat

Successful spawning and development from egg to fry require:

- absence of barriers to upstream migration of adults,
- spawning areas with sediment-free substrate and adequate water flows,

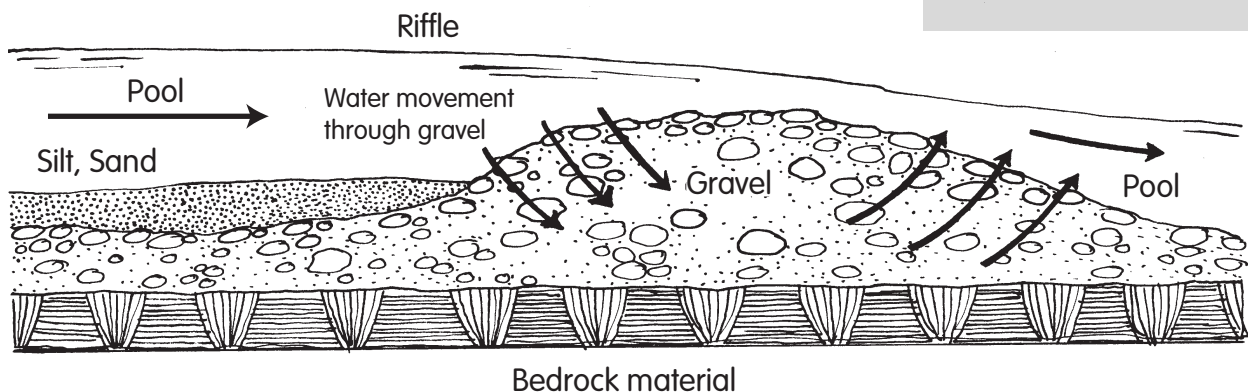
- a balance of pools to riffles that provides spawning areas and nearby escape cover, and
- a constant flow of cool, well-oxygenated water through the spawning gravel.

Anadromous fish must be able to move upstream to spawning areas. Log jams and other barriers can prevent this from happening. Fish can injure themselves trying to jump barriers or become weak and exhausted, reducing chances for successful spawning.

In ideal spawning habitat, cool, well-oxygenated water flows freely through sediment-free gravel areas. The cleanest gravel is usually found at the tailout, or downstream end, of a pool. Heavy flooding can disturb spawning beds in unstable channels.

Vocabulary

carrying capacity



Adapted from: Province of British Columbia, Ministry of Environment, *Stream Enhancement Guide*, Vancouver, B.C., 1980.

Rearing habitat

Young fry are vulnerable to predators, as they leave the gravel to seek food. High stream velocities can carry fry far downstream or strand them in floodplain pools. To enhance the survival of fry, pools for rearing, temperature regulation and cover should be close to each other. Productive juvenile rearing habitat requires:

- low to moderate slope and velocity;
- a balance of pool and riffle habitat;
- a variety of substrate types to provide hiding cover for juvenile fish and places for aquatic insects to live;
- undercut banks, stable natural debris such as fallen trees, and overhanging vegetation to provide cooling shade and protection for juvenile fish, and leaf litter for aquatic insect production; and
- sufficient nutrients to promote growth of naturally occurring plants and other organisms beneficial to the stream.

As young salmonids grow, they seek progressively higher velocities, often moving from the edge of a stream to midstream to take advantage of increased insect drift. Facing upstream or into the current allows a fish to conserve energy while watching for food drifting downstream.

Facing upstream or into the current allows a fish to conserve energy while watching for food drifting downstream.

In winter, all species seek areas of lower water velocity. This helps conserve energy while food and growing conditions are poorer, enabling fish to better cope with winter extremes.

Habitat preferences

Though basic requirements are the same, salmonid species differ in the types of habitat they use. For example, juvenile coho choose pool areas of moderate velocity in summer. They prefer eddies or backwaters near an undercut bank, root wad or log. In winter, they are found in slow, deep pools or side channel areas, seeking cover under rocks, logs and debris.

During winter, spring chinook salmon use riparian edges where vegetation has grown into a stream, providing cover and shelter. Streambanks must be covered with vegetation to provide this feature. Degraded streambanks do not provide suitable winter habitat for young fish. Rearing

Rearing densities can increase dramatically where good streambank recovery has occurred.

densities can increase dramatically where good streambank recovery has occurred.

Juvenile steelhead spend from one to three years in fresh water, and their habitat needs must be considered throughout that time. In the first summer after hatching, young steelhead stay in relatively shallow, cobble-bottomed areas at the tail of a pool or shallow riffle. In winter, they hide under large boulders in shallow riffle areas.

Older steelhead juveniles prefer the heads of pools and riffles with large boulder substrate and woody cover in the summer. The turbulence created by this substrate is also important cover in these areas. During winter, older steelhead juveniles are found in pools, near streamside cover and under debris, logs or boulders.

Cutthroat habitat requirements are similar to those of steelhead, and although chinook juveniles tend to rear in large streams, their requirements parallel those of coho.

Table 4. Salmonids and Physical Stream Characteristics

Habitat preference	Species			
	Coho	Chinook	Steelhead	Cutthroat
% pools	50-80	50-100	< 50	40-60
% gradient	<3	< 2	>1-5	1-20
Stream order	2-5	≥ 5	2-5	> 2
Maximum temperature	<65°F 18°C	< 68°F 20°C	< 73°F 23°C	< 65°F 18°C

Physical stream characteristics useful in evaluating stream quality preferences for salmonids.

Characteristics	Coho	Chinook	Steelhead	Cutthroat
Cover	woody structure	pool depth	boulders & wood	wood, volume, boulders
Channel profile	flat	moderately flat	steep	undercut banks
Riparian	Presence of riparian vegetation important for all species. Vegetation type (fir, alder) and age of vegetation determine quality.			

Limiting factors

Limiting factors must be considered for all phases of a salmonid's life cycle. The quantity and quality of riffle areas and spawning gravels in a stream limit spawning production. The quantity and quality of juvenile nursery areas or pools is a limiting factor for rearing juvenile salmonids and producing smolts ready for migration to the ocean.

When spawning habitat is limited, excessive numbers of adults on the spawning beds dislodge previously deposited eggs. If too many juveniles exist in rearing areas, competition for food and space force some to move into less suitable areas. These areas may have limited food and shelter from predators.

These limiting factors establish the salmonid **carrying capacity** of a stream. Within the limits of the available habitat, salmonid populations

fluctuate from year to year because of varying environmental factors.

Streamflow, for example, causes wide variations in survival and production of coastal salmonid populations. Extended low flows may keep adults from moving into streams, drain their limited energy reserves and affect upstream distribution and spawning success. High winter flows can destroy eggs and alevins by scouring spawning beds or depositing sediments. Low stream flows during winter incubation periods can cause exposure and freezing of spawning beds. Low summer flows often allow stream temperatures to increase, which reduces rearing

areas for juveniles.

Stream temperatures may also affect survival indirectly. Abnormally high temperature conditions during migration have contributed to

Limiting factors establish the salmonid carrying capacity of a stream.

outbreaks of disease among adults, causing them to die before spawning. High winter temperatures increase the rate of development from egg to fry, and may cause fry to emerge from the gravel before the spring increase in food supplies.

A critical issue in eastern Oregon is the buildup of heavy ice (anchor ice) in streams. **Anchor ice** can trap fish in pockets where they freeze and die. Healthy riparian systems and stable streambanks help reduce heavy anchor ice and winter mortality of juvenile fish.

Recommended habitat conditions

As a stream is surveyed and analyzed, consider the habitat needs and stream quality references of the several salmonid species listed in Table 4 to ensure the best possible management of the resource.

Following is a list of other conditions that may improve the quality of fish habitat in streams. This list was prepared by the Riparian Habitat Subcommittee of the Oregon and Washington Interagency Wildlife Committee. Included is an explanation of how each contributes to salmonid health and survival.

Between 60% and 100% of a stream surface should be shaded from June to September during the hours of 10:00 A.M. to 4:00 P.M.

- Solar radiation is greatest during this season and time of day. Streamside vegetation provides shade to help keep water temperatures from becoming lethal during hot summer months. Streambank vegetation is also important habitat for terrestrial insects and is the main nutrient source for aquatic insects. These are both important sources of fish food. Shade is most important on small streams (less than 50 feet wide). Water depth and turbulence help compensate for the lack of shade on large streams.

Stream banks should have 80% or more of their total linear distance in a stable condition.

- Stable, well-vegetated streambanks help maintain stream channel integrity. They provide cover for fish and reduce temperature increases from solar radiation. In winter, they keep water temperatures slightly warmer, reducing ice buildup and decreasing winter mortality of juvenile fish. Sediments from streambanks are reduced, protecting the water quality of the entire system. Vegetation reduces bank erosion and helps hold the soil in place. Sediments are trapped and mature grasses and forbs form a strong sod.

No more than 15% of stream substrate should be covered by inorganic sediment.

- Aquatic insects, developing salmonid eggs and recently hatched fry still in the gravel depend on a continuous supply of cool, oxygen-rich water for survival. Large amounts of fine sediments clog the spaces between gravels. This prevents water from percolating through and causes fish and insect mortality. If pools are filled with sediments, rearing and hiding habitat is reduced or eliminated.

Bibliography

Borton, Wendy, et al. *Clean Water, Streams, and Fish: A Holistic View of Watersheds*. Seattle: Municipality of Metropolitan Seattle, no date available.

Claire, Errol. "Twenty-Seven Year Summary of Chinook Salmon Spawning Density, John Day District, 1959-1986." (mimeographed).

Adapted from: Province of British Columbia, Ministry of Environment, *Stream Enhancement Guide*, Vancouver, B.C., 1980; and Riparian Habitat Subcommittee of the Oregon/Washington Interagency Wildlife Committee, *Managing Riparian Ecosystems (Zones) for Fish and Wildlife in Eastern Oregon and Eastern Washington*, Portland, OR, December 12, 1978.

- Harrison, George. "Journey of a Stream." *Sports Afield*, March, 1987, pp. 52-54.
- Hughes, Dave. "Anatomy of a Trout Stream." *Outdoor Life*, June 1986, pp. 64, 110-112.
- Johnson, Phillip. "Learning the Language of a Stream." *National Wildlife*, August-September 1986, pp. 30-35.
- Kopec, John, and Stuart Lewis. *Stream Quality Monitoring*. Charleston, Oregon: Ohio Department of Natural Resources and Pacific Fisheries Enhancement, no date available.
- McNally, Bob. "Fish the Magic Edges." *Outdoor Life*, April, 1982, pp. 41-43.
- Maser, Chris, and James M. Trappe., *The Seen and Unseen World of the Fallen Tree*. Washington, D.C.: U.S. Department of the Interior, Bureau of Land Management, 1984.
- Oregon (formerly Governor's) Watershed Enhancement Board. *Oregon Aquatic Habitat Restoration and Enhancement Guide*. Oregon Plan for Salmon and Watersheds, Salem, Oregon, May 1999.
- Perich, Shawn. "Sportsman's Guide to Reading a River." *Fins And Feathers*, June 1986, pp. 64-65.
- Platts, William S., et al. *Methods for Evaluating Riparian Habitats with Applications to Management*. General Technical Report INT-221, U.S. Department of Agriculture, Forest Service, 1987.
- Platts, William S., et al. *Methods For Evaluating Stream Riparian and Biotic Conditions*. Ogden, Utah: U.S. Department of Agriculture, 1983.
- Province of British Columbia, Ministry of Environment. *Stream Enhancement Guide*. Vancouver, B.C.: 1980.
- Reiser, D.W., and T.C. Bjornn. *Influence of Forests and Rangeland Management on Anadromous Fish Habitat in Western North America: Habitat Requirements of Anadromous Salmonids*. Portland: U.S. Department of Agriculture, Forest Service, 1979.
- Riparian Habitat Subcommittee of the Oregon/ Washington Interagency Wildlife Committee. *Managing Riparian Ecosystems (Zones) for Fish and Wildlife in Eastern Oregon and Eastern Washington*. Portland, December 12, 1978.
- Sedell, James R., and Karen J. Luchessa. "Using The Historical Record as an Aid to Salmonid Fish Habitat Enhancement." Presentation to Symposium on Aquisition and Utilization of Aquatic Habitat Inventory Information, Portland, Oregon, October 23-28, 1981.
- Sedell, James R., et al. "Fish Habitat and Streamside Management: Past and Present." Presentation to Society of American Foresters, annual meeting, Bethesda, Maryland, September 27-30, 1981.
- Stoker, Daniel G., et al. *A Guide to the Study of Fresh Water Ecology*. Englewood Cliffs, NJ: Prentice-Hall, 1972.
- Triska, F.J., et al. "Coniferous Forest Streams." In Robert L. Edmonds, (ed.), *Analysis of Coniferous Forest Ecosystems in the Western United States*, Stroudsburg, PA: Hutchinson Ross Publishing Company, 1982.
- U.S. Department of Agriculture, Forest Service, National Marine Fisheries Service, and Alaska Department of Fish and Game. *Fish in the Forest: Large Woody Debris in Streams: A New Management Approach to Fish Habitat*. R10-FR-1, September, 1986.

Home wet home . . .

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Guide for more specific information. You can get it from the Oregon (formerly Governor's) Watershed Enhancement Board (phone: 503-378-3589).

Objectives

The student will (1) recognize the habitat components necessary for salmonids in a stream, and (2) analyze and describe how each stream structure contributes to salmonid habitat needs.

Method

Students read background material, observe and analyze the stream diagram, and describe how each item noted develops or provides salmonid habitat.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. This activity builds on knowledge from prior activities. Constructing a model stream where students can manipulate structures would be more effective for younger students.

Materials

- copies of student sheets (pp. 397-398)

Notes to the teacher

Because a number of fish species in Oregon are classified as threatened or endangered under the Endangered Species Act, fish restoration activities are closely monitored. Consult the *Oregon Aquatic Habitat Restoration and Enhancement*

Background

Do you know . . .

Salmon and trout (salmonids) are important to anglers. Salmonids are also important to biologists because their presence helps indicate the health of the stream in which they live. Salmonids are one of the first organisms to be affected if their watery home starts to change or if their habitat is unsuitable. Biologists refer to sensitive animals like salmonids as "indicator" species.

Although a healthy natural habitat is preferred, fish biologists have developed many ways to improve degraded stream habitat to enhance fish survival. In some cases, biologists can produce a fishery where none was previously found.

The ecological requirements of salmonids are:

- cool, clear, well-oxygenated water,
- sections of gravel bottom for spawning,
- occasional pools for feeding and resting,

Vocabulary

boulder cluster	rip rap
cover logs	rock weir
cover tree	rock wing deflector
gravel bar	root wad
log sill	shade plantings
pool	streamside vegetation

- adequate food (aquatic and terrestrial insects, the latter usually falling from streamside vegetation), and
- cover for protection from predators.

Procedure

Now it's your turn . . .

How do you make a house a home? A house is just walls, a floor and a roof. But to make it a home, you have to arrange the furniture and hang the pictures. Structures like chairs, sofas, tables, beds, and your favorite wall hangings make the house more comfortable and livable.

Fish also need homes. A stream without structures like rocks, plants, logs, boulders, and gravel is just a “house.” But with those structures in the stream and arranged just so, fish can live there comfortably.

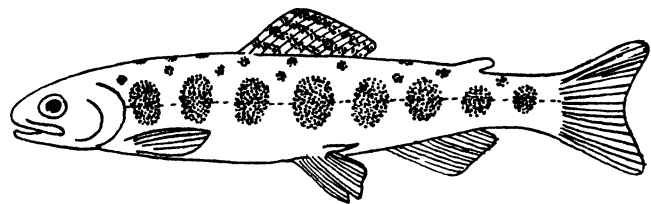
In a healthy stream, nature creates fish “homes” with all the right furnishings. But many streams today are not healthy and have lost their ability to serve as good homes for fish. So, fish biologists often build structures in and around streams to help restore fish habitat so that more fish can live there. They create pools, riffles, curves, and bends and grow plants along the stream. They also try to make the new changes look as natural as possible.

Following is a drawing of a stream that biologists have been working on. They have created each of the lettered structures. Can you tell how each structure helps fish live there? For instance, Item A—streamside vegetation—provides shade to keep the water cool and creates food (leaves) for insects that live in the water, which are in turn eaten by the fish.

Test your knowledge about fish habitat. Describe how each features serves as fish habitat in the space provided on the student answer sheet.

Going further

1. Repeat the “Temperature and Respiration Rate” experiment (pp. 265-268) using other species of fish (some warm water species and some cold water species). Compare the results. Based on your results, discuss why different species are found in completely different environments or in different parts of the same stream.
2. Design an experiment to measure the rate of flow in riffles and pools (and other habitat types including glides, rapids, and cascades.) Research the different types of fish habitat, including all kinds of slow-water and fast-water habitats. Consult with a fish habitat biologist to learn how each of the habitat types provides for the needs of fish. Prepare a report or display of your findings and present to the class.
3. Investigate the types of restoration work that are appropriate along a stream that has been severely damaged by flooding, heavy erosion, or other events. Explore the possibility of a work team from your school assisting others in the community to complete restoration work on a stream. Research who has responsibility for coordinating work projects of this type and the requirements necessary to proceed.
4. Have students build a stream table (model stream) to test different structures to control streamflow and erosion.



A. streamside vegetation
Provides cover in addition to shade for temperature regulation. In autumn, leaves drop into stream and eventually provide food for invertebrates that are eaten by fish.

B. rock weir
Slows the water, traps gravel for spawning, and creates pools.

C. root wad
Provides shade, cover, and resting areas, and produces spot scouring.

D. cover logs
Provides shade, cover, and resting areas, and produces spot scouring.

E. rip rap (rocks or vegetative)
Protects banks from erosion.

F. rock wing deflector
Redirects water flow, causes gravel deposition, and creates pools or pocket water and resting areas.

G. shade plantings
Provides shade for water temperature regulation and food for invertebrates when leaves fall.

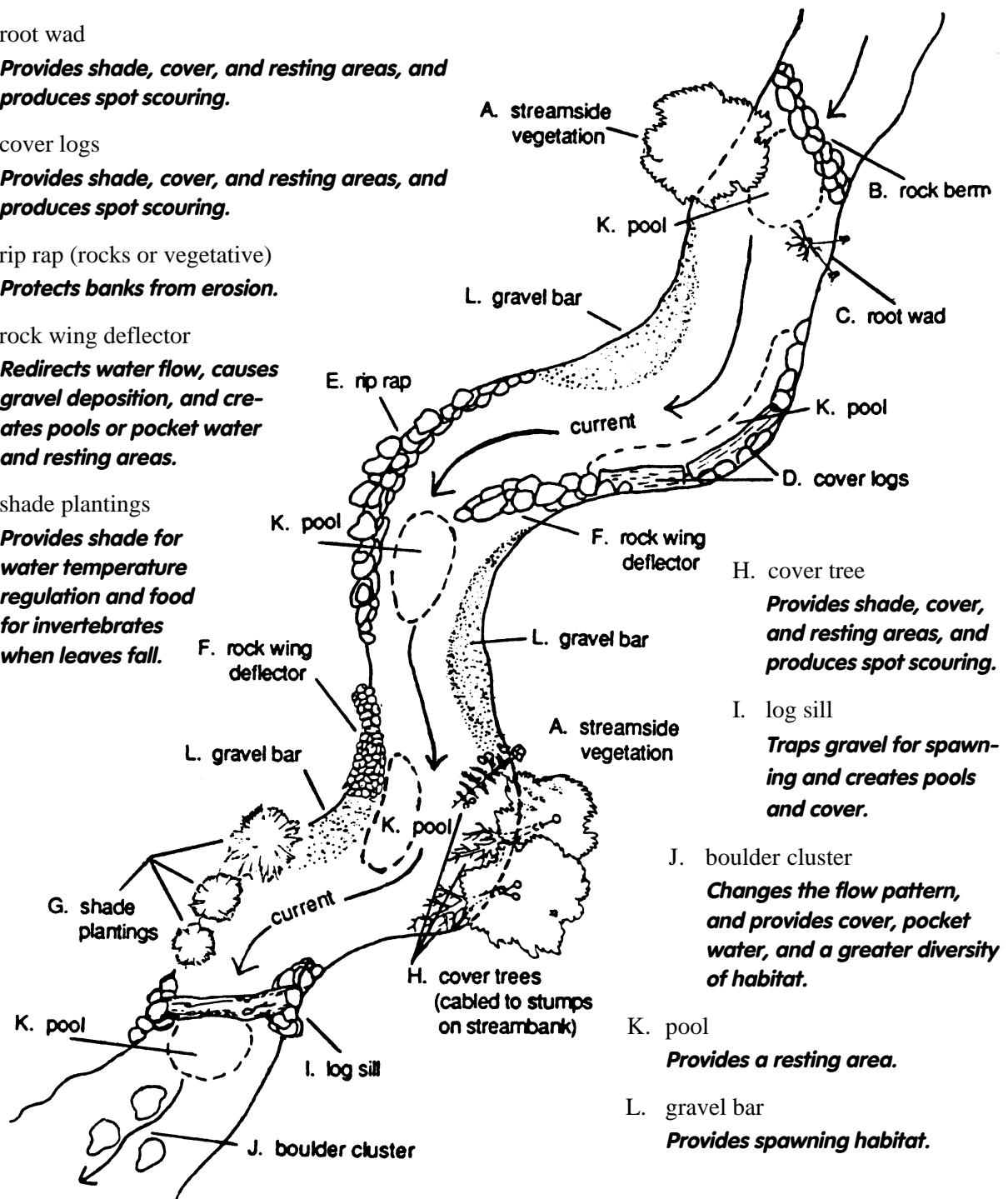
H. cover tree
Provides shade, cover, and resting areas, and produces spot scouring.

I. log sill
Traps gravel for spawning and creates pools and cover.

J. boulder cluster
Changes the flow pattern, and provides cover, pocket water, and a greater diversity of habitat.

K. pool
Provides a resting area.

L. gravel bar
Provides spawning habitat.



Home wet home . . .

Do you know . . .

Salmon and trout (salmonids) are important to anglers. Salmonids are also important to biologists because their presence helps indicate the health of the stream in which they live. Salmonids are one of the first organisms to be affected if their watery home starts to change or if their habitat is unsuitable. Biologists refer to sensitive animals like salmonids as “indicator” species.

Because salmonids are so significant, fish biologists have developed many ways to improve stream habitat to enhance fish survival. In some cases, biologists can produce a fishery where none was previously found.

The ecological requirements of salmonids are:

- cool, clear, well-oxygenated water,
- sections of gravel bottom for spawning,
- occasional pools for feeding and resting,
- adequate food (aquatic and terrestrial insects, the latter usually falling from streamside vegetation), and
- cover for protection from predators.

Now it's your turn . . .

How do you make a house a home? A house is just walls, a floor and a roof. But to make it a home, you have to arrange the furniture and hang the pictures. Structures like chairs, sofas, tables, beds, and your favorite wall hangings make the house more comfortable and livable.

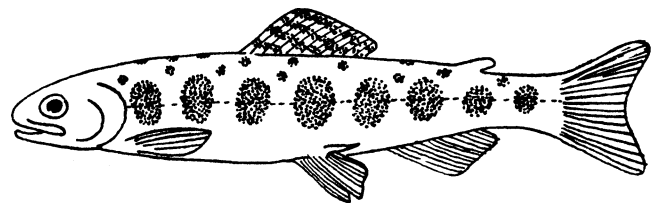
Fish also need homes. A stream without structures like rocks, plants, logs, boulders, and gravel is just a “house.” But with those structures in the stream and arranged just so, fish can live there comfortably.

In a healthy stream, nature creates fish “homes” with all the right furnishings. But many

streams today are not healthy and have lost their ability to serve as good homes for fish. So, fish biologists often build structures in and around streams to help restore fish habitat so that more fish can live there. They create pools, riffles, curves, and bends and grow plants along the stream. They also try to make the new changes look as natural as possible.

Following is a drawing of a stream that biologists have been working on. They have created each of the lettered structures. Can you tell how each structure helps fish live there? For instance, Item A—streamside vegetation—provides shade to keep the water cool and creates food (leaves) for insects that live in the water, which are in turn eaten by the fish.

Test your knowledge about fish habitat. Describe how each features serves as fish habitat in the space provided on the student answer sheet.



Vocabulary

boulder cluster	rip rap
cover logs	rock weir
cover tree	rock wing deflector
gravel bar	root wad
log sill	shade plantings
pool	streamside vegetation

Student sheet

A. streamside vegetation

B. rock weir

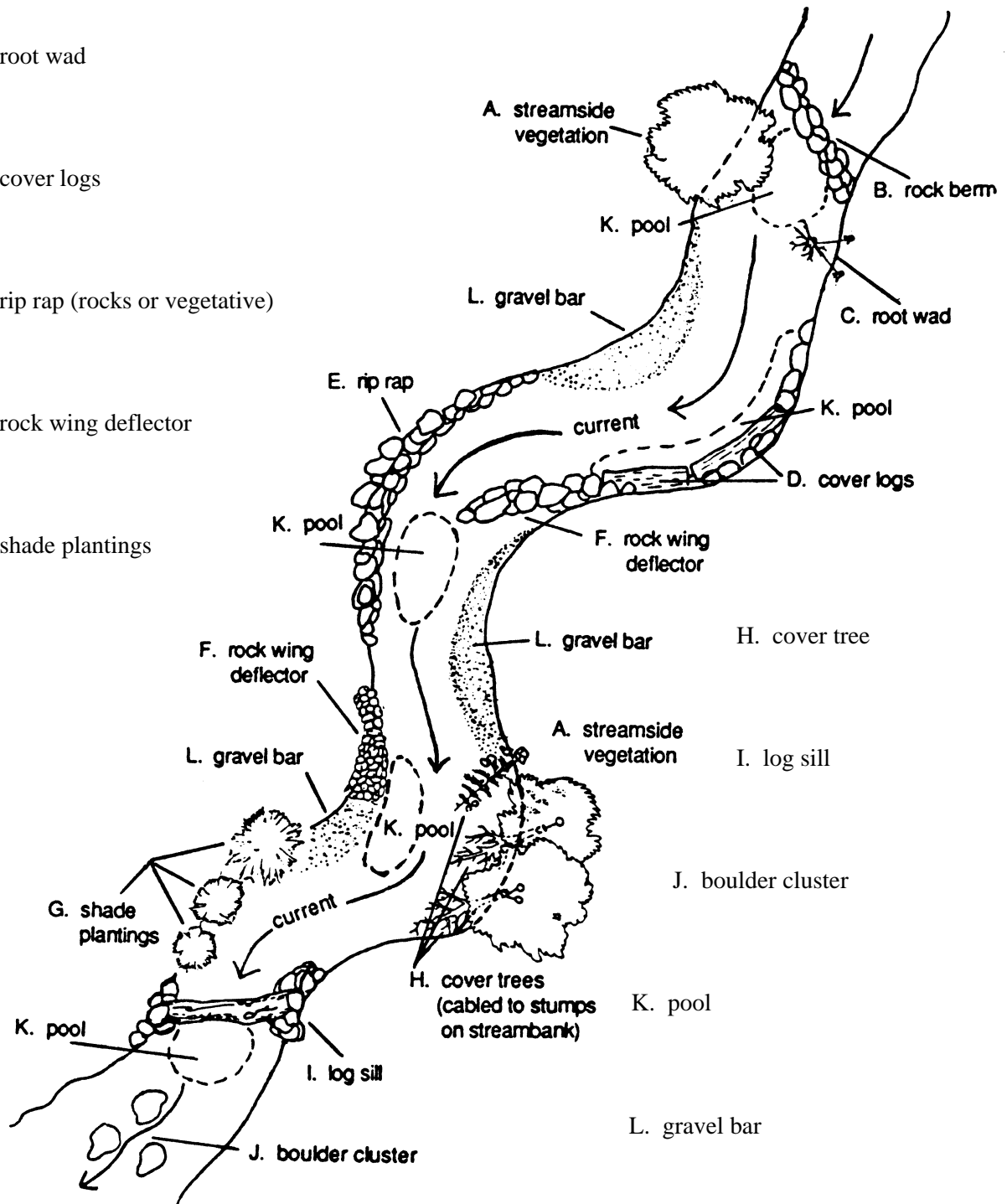
C. root wad

D. cover logs

E. rip rap (rocks or vegetative)

F. rock wing deflector

G. shade plantings



H. cover tree

I. log sill

J. boulder cluster

K. pool

L. gravel bar

Student sheet

The stream doctor— a fish biologist at work

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

Students will (1) calculate the average number of redds per mile for the John Day River system; (2) graph and compare the spawning densities of chinook salmon in the mainstem, North Fork, and Middle Fork of the John Day River before and after riparian habitat improvement work; and (3) describe what influence stream habitat improvement work can have on fish numbers.

Method

Students graph spawning ground survey data for chinook salmon in the John Day Basin. The students then make comparisons and draw conclusions as to the effects of habitat improvement on these particular streams.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. To make the complex graph easier to read for younger students, use clear overlays or a larger chart paper and break the graphing procedure into steps. Simply ques-

Vocabulary

redds
spawning

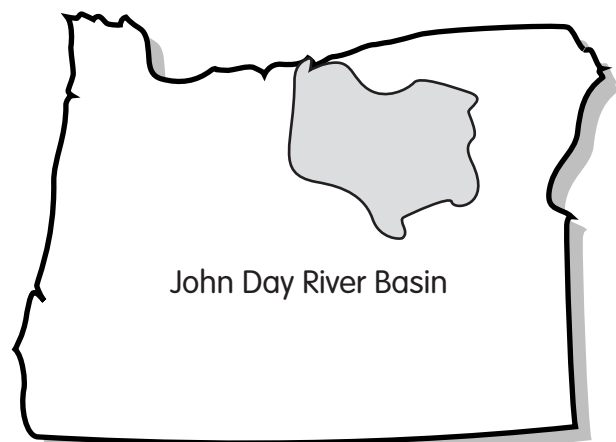
Materials

- copies of student sheets (pp.405-408)

Notes to the teacher

Following are graph interpretation comments provided by the John Day Basin fish biologist.

The Middle Fork John Day River and John Day River are the most graphic in terms of recovery, which just happens to coincide with the amount of habitat work that has been done. Most of the habitat work on the Middle Fork is the result of better livestock management on U.S. Forest Service lands, a Nature Conservancy Preserve, and riparian fencing on a private ranch. Almost all the habitat work on the John Day River has been on private land. A typical project may consist of riparian fencing, removal of push-up irrigation dams, more efficient irrigation systems, converting from flood irrigation to gated pipe or sprinkler), or elimination of irrigation return water (installing drain pipe under the field and routing it directly to the river). Where return water has



Adapted from Jim Gladson, "The Stream Doctor," *Oregon Wildlife*, July 1983.

been eliminated, we have seen an 11°F temperature change (inflow prior to the project was 11°F warmer than after completion). At least one ranch has seen a doubling of hay production by converting to gated pipe from flood irrigation. Thus restoration activity not only benefits the fish, but benefits the landowner.

Background

Do you know . . .

Protection and improvement of riparian habitat in the John Day River Basin are serious subjects. Years of livestock grazing to the water's edge and poor land-use practices left bare and broken-down banks on many John Day streams. Without cooling shade, the waters warmed in the direct sun. Without the binding root systems of growing plants, banks collapsed and loaded the streams with silt.

*The soil is the “money” and
vegetation acts as the
“security system.”*

By the late 1960s, streams that had once produced good runs of wild salmon and steelhead were in poor shape. Very few of these fish were able to survive in the warm, murky water. Other fish, such as squawfish, chiselmouth and shiners, could adjust to the change. These fish, not valued by anglers, began to take over the habitat. This invasion of non-game fish became so serious the North Fork of the John Day River had to be poisoned to remove them.

Errol Claire, a fish biologist with the Oregon Department of Fish and Wildlife in John Day and a pioneer in riparian restoration, saw the natural system breaking down and knew something had to be done. He set up a program to make the riparian habitat on the South Fork John Day

River and its tributary, Murderer's Creek, healthy again. In 1982, the Bonneville Power Administration (BPA) also began several projects to help pay for riparian habitat restoration in the John Day system. The success of these efforts is evaluated as adult fish return to their home streams.

To improve riparian habitat, work must begin with the streambanks themselves. In fact, you can literally think of them as “banks.” The soil is the “money” and vegetation acts as the “security system.” In a natural system, the soil “money” is deposited a little at a time, and the vegetation “security system” guards it. The bank is rich. If we take away the security system (vegetation), then the natural system changes. Wind, rain and other eroding forces make withdrawals from the soil “bank” without replacing the soil “money.” The bank becomes poor and useless. Practices, like *unmanaged* livestock grazing and others, that allow vegetation removal to the stream's edge, are like “robbing the bank.”

Through riparian restoration projects, miles of streambanks have been fenced to keep cattle away from fragile banks and allow vegetation to re-grow. Rotating cattle grazing schedules has permitted some riparian areas to recover. Willows have been planted to protect and keep the banks from collapsing into the water. Riprap, rock and cut junipers have also been placed in streams to reduce bank erosion.

Miles of water that had poor spawning or rearing habitat have also been improved. Placement of boulders and logs in the stream has made the habitat more attractive to fish, especially salmon and trout. Pollution sources, like abandoned mines, have been identified and controlled. Clearing log jams and placing fish ladders have helped in areas with poor fish passage.

Fish populations are making a comeback in restored areas. Researchers have found more salmonids in cool, clear streams that have healthy riparian vegetation than in warmer, silty water with no protective riparian vegetation.

Procedure

Now it's your turn . . .

The information in the table on this page is valuable to biologists because it shows trends in the numbers of chinook salmon spawning in the John Day River and its tributaries over an extended period of time. In this exercise you will graph and compare the spawning densities of chinook salmon from three streams.

When fish lay eggs it is called **spawning**. Nests, or **redds**, prepared by the female are circular holes dug in the gravel in the stream bottom. The male drives away all other fish from his selected mate and fertilizes the eggs as the female deposits them.

When water conditions are low and clear, the redds are visible from the streambank. To discover how many salmon are spawning in a drainage basin, fish biologists count the number of redds, or fish nests, per mile on certain streams (called index streams) in the area. Difficult viewing conditions, like high, murky water, can make fish counts seem lower than normal. For example, in 1972, the count of redds per mile on the John Day River was low because of heavy rains.

Look at the information presented in the table on this page. It represents a portion of a nearly 40-year study of 116 total miles of index streams in the John Day Basin. Begin by:

- Calculating the average number of redds per mile for each stream. Record the average in the box provided at the end of the table.
- On the graph on page 403, starting with the John Day River, create a line graph by plotting the number of redds per mile for each of the 32 years of data. Repeat the process for the Middle Fork and the North Fork and the average.
- **Use a different color for each of the three lines.**
- **Be sure to mark the legend with the color representing each line.**

Chinook Salmon Spawning Density, John Day District, 1967-1998

Year	John Day River	Middle Fork John Day River	North Fork John Day River
1967	7.4	1.7	5.5
1968	0.7	0.4	8.8
1969	9.3	4.8	20.5
1970	8.3	7.6	16.8
1971	7.0	4.1	11.8
1972	**3.9	5.1	10.5
1973	8.9	4.3	19.4
1974	2.5	8.1	7.2
1975	7.1	8.9	11.7
1976	4.6	6.6	6.2
1977	4.9	5.8	16.4
1978	4.5	10.7	5.9
1979	5.2	11.8	11.1
1980	1.2	5.8	4.3
1981	3.9	2.6	7.7
1982	3.8	6.2	5.5
1983	10.2	5.1	4.2
1984	5.6	6.7	3.5
1985	8.9	4.0	6.1
1986	12.2	6.3	14.3
1987	19.0	28.3	20.8
1988	6.3	20.1	13.6
1989	12.7	9.4	10.9
1990	9.5	3.9	14.3
1991	4.7	2.9	6.4
1992	10.9	9.0	18.8
1993	10.4	12.9	21.1
1994	13.0	7.8	11.2
1995	2.2	1.3	1.5
1996	17.5	11.3	16.2
1997	9.6	13.6	10.9
1998	8.3	6.6	5.6

Average	8.6	8.9	10.2
----------------	------------	------------	-------------

** Count low due to rain and increased river flow that delayed survey and caused poor counting conditions.

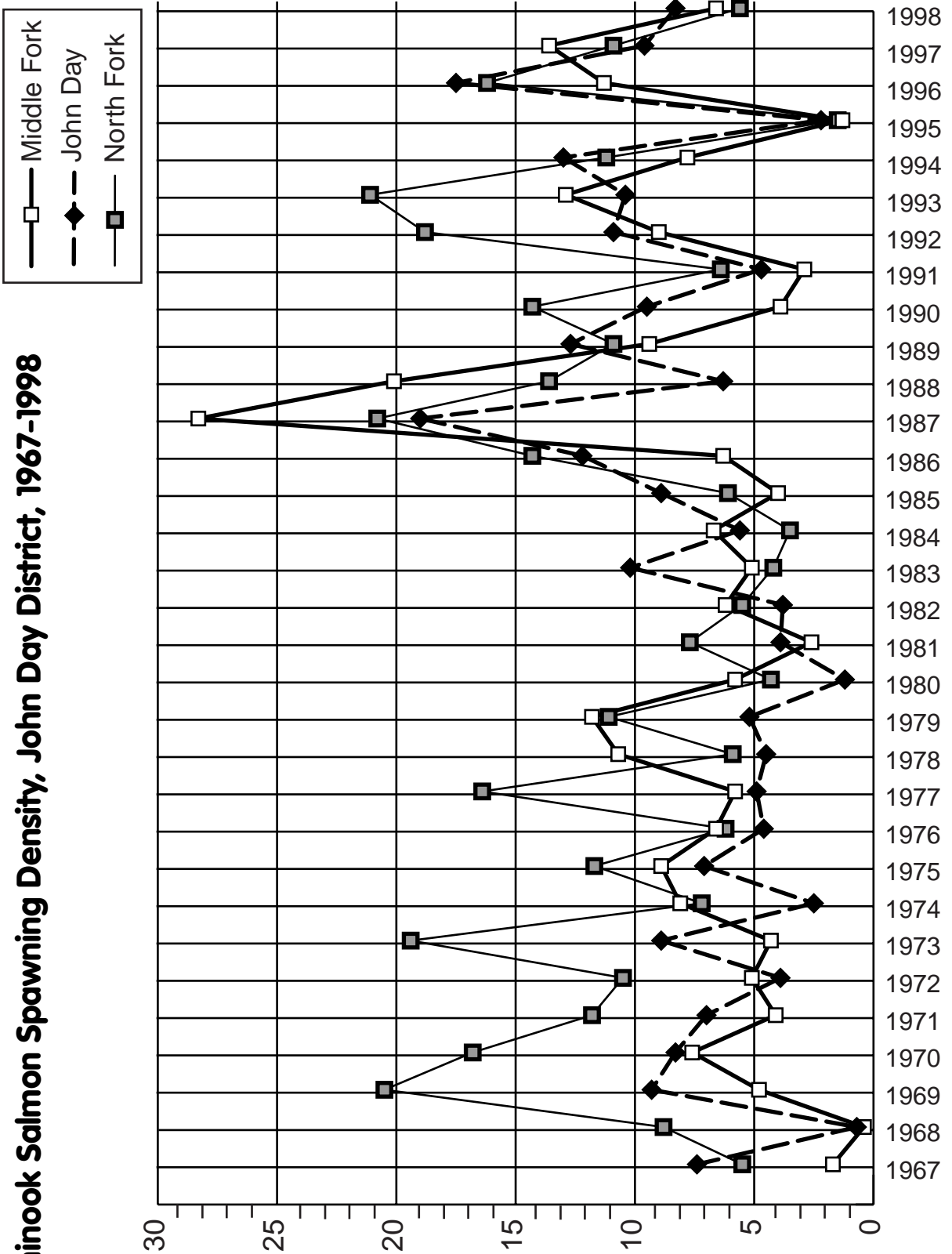
Questions

1. Look carefully at the overall picture of how John Day Basin spawning fish populations have changed throughout the years. Do the peaks and valleys for each stream's line parallel each other? Describe the general trends and comparisons you see on the graph.
Lines basically parallel each other. Seems unstable.
2. Describe any change in the pattern for the years 1977 to 1989. What has happened since 1990?
Still unstable, but generally lower average than previous decade; 1986-89 shows slight upward trend. From 1990 to 1993, upward trend then a marked drop in 1995.
3. Which stream had the lowest average redds per mile?
Mainstem John Day River.
4. Referring to the introductory information, what human activity may have helped increase the number of redds per mile on the North Fork John Day in the late 1960s?
Removal of competition from non-game fish by poisoning.
5. Looking at the overall trends on the graph, do you notice any changes after 1984? Describe what you see. Why do you think this is happening?
Yes. More consistent increases in the number of redds per mile on all but the Middle Fork. The new habitat restoration work has been in place long enough to show fish population responses.
6. List as many ways as you can to describe how stream habitat restoration efforts can help increase fish populations?
Answers will vary, but should include improvement of spawning and rearing habitat, protection of eroding streambanks, riparian area protection, etc.
7. What are the things a "stream doctor" must know to be effective in restoring a stream?
Answers will vary, but could include kinds of fish currently and historically present in the stream, habitat requirements of the fish in the stream, streamflow pattern of the stream, location of irrigation diversions, key erosion points and the reason for them, locations of barriers to fish migration, etc.

Going further

1. Contact your local department of fish and wildlife. Invite a fisheries biologist to review the data from this activity with you and make his or her own analysis. Does it differ significantly from your own? If so, how?
2. Contact your local department of fish and wildlife. Volunteer to assist with fish spawning surveys on streams in your area. Ask the local fisheries biologist to show you how the data is analyzed and presented. Prepare a report and share this information with the class.
3. Have students build a stream table (model stream) to test different structures to control streamflow and erosion.

Chinook Salmon Spawning Density, John Day District, 1967-1998



The stream doctor— a fish biologist at work

Do you know . . .

Protection and improvement of riparian habitat in the John Day River Basin are serious subjects. Years of livestock grazing to the water's edge and poor land-use practices left bare and broken-down banks on many John Day streams. Without cooling shade, the waters warmed in the direct sun. Without the binding root systems of growing plants, banks collapsed and loaded the streams with silt.

By the late 1960s, streams that had once produced good runs of wild salmon and steelhead were in poor shape. Very few of these fish were able to survive in the warm, murky water. Other fish, such as squawfish, chiselmouth and shiners, could adjust to the change. These fish, not valued by anglers, began to take over the habitat. This invasion of non-game fish became so serious the North Fork of the John Day River had to be poisoned to remove them.

Errol Claire, a fish biologist with the Oregon Department of Fish and Wildlife in John Day and a pioneer in riparian restoration, saw the natural system breaking down and knew something had to be done. He set up a program to make the riparian habitat on the South Fork John Day River and its tributary, Murderer's Creek, healthy again. In 1982, the Bonneville Power Administration (BPA) also began several projects to help pay for riparian habitat restoration in the John Day system. The success of these efforts is evaluated as adult fish return to their home streams.

To improve riparian habitat, work must begin with the streambanks themselves. In fact, you can literally think of them as "banks." The soil is the

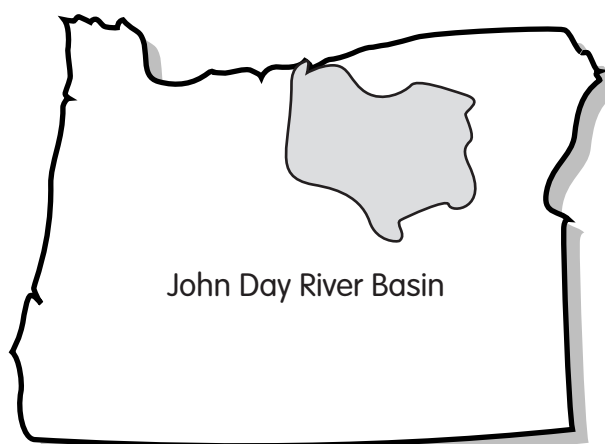
Vocabulary

redds
spawning

"money" and vegetation acts as the "security system." In a natural system, the soil "money" is deposited a little at a time, and the vegetation "security system" guards it. The bank is rich. If we take away the security system (vegetation), then the natural system changes. Wind, rain and other eroding forces make withdrawals from the soil "bank" without replacing the soil "money." The bank becomes poor and useless. Practices, like *unmanaged* livestock grazing and others, that allow vegetation removal to the stream's edge, are like "robbing the bank."

Through riparian restoration projects, miles of streambanks have been fenced to keep cattle away from fragile banks and allow vegetation to re-grow. Rotating cattle grazing schedules has permitted some riparian areas to recover. Willows have been planted to protect and keep the banks from collapsing into the water. Riprap, rock and cut junipers have also been placed in streams to reduce bank erosion.

Miles of water that had poor spawning or rearing habitat have also been improved.



Adapted from Jim Gladson, "The Stream Doctor," *Oregon Wildlife*, July 1983.

Placement of boulders and logs in the stream has made the habitat more attractive to fish, especially salmon and trout. Pollution sources, like abandoned mines, have been identified and controlled. Clearing log jams and placing fish ladders have helped in areas with poor fish passage.

Fish populations are making a comeback in restored areas. Researchers have found more salmonids in cool, clear streams that have healthy riparian vegetation than in warmer, silty water with no protective riparian vegetation.

Now it's your turn . . .

The information in the table on the following page is valuable to biologists because it shows trends in the numbers of chinook salmon spawning in the John Day River and its tributaries over an extended period of time. In this exercise you will graph and compare the spawning densities of chinook salmon from three streams.

When fish lay eggs it is called **spawning**. Nests, or **redds**, prepared by the female are circular holes dug in the gravel in the stream bottom. The male drives away all other fish from his selected mate and fertilizes the eggs as the female deposits them.

When water conditions are low and clear, the redds are visible from the streambank. To discover how many salmon are spawning in a drainage basin, fish biologists count the number of redds, or fish nests, per mile on certain streams (called index streams) in the area. Difficult viewing conditions, like high, murky water, can make fish counts seem lower than normal. For example, in 1972, the count of redds per mile on the John Day River was low because of heavy rains.

Look at the information presented in the following table. It represents a portion of a nearly 40-year study of 116 total miles of index streams in the John Day Basin. Begin by:

- Calculating the average number of redds per mile for each stream. Record the average in the blank provided with the table.
- On the graph provided, starting with the John Day River, create a line graph by plotting the number of redds per mile for

Chinook Salmon Spawning Density, John Day District, 1967-1998

Year	John Day River	Middle Fork John Day River	North Fork John Day River
1967	7.4	1.7	5.5
1968	0.7	0.4	8.8
1969	9.3	4.8	20.5
1970	8.3	7.6	16.8
1971	7.0	4.1	11.8
1972	**3.9	5.1	10.5
1973	8.9	4.3	19.4
1974	2.5	8.1	7.2
1975	7.1	8.9	11.7
1976	4.6	6.6	6.2
1977	4.9	5.8	16.4
1978	4.5	10.7	5.9
1979	5.2	11.8	11.1
1980	1.2	5.8	4.3
1981	3.9	2.6	7.7
1982	3.8	6.2	5.5
1983	10.2	5.1	4.2
1984	5.6	6.7	3.5
1985	8.9	4.0	6.1
1986	12.2	6.3	14.3
1987	19.0	28.3	20.8
1988	6.3	20.1	13.6
1989	12.7	9.4	10.9
1990	9.5	3.9	14.3
1991	4.7	2.9	6.4
1992	10.9	9.0	18.8
1993	10.4	12.9	21.1
1994	13.0	7.8	11.2
1995	2.2	1.3	1.5
1996	17.5	11.3	16.2
1997	9.6	13.6	10.9
1998	8.3	6.6	5.6

Average			
----------------	--	--	--

** Count low due to rain and increased river flow that delayed survey and caused poor counting conditions.

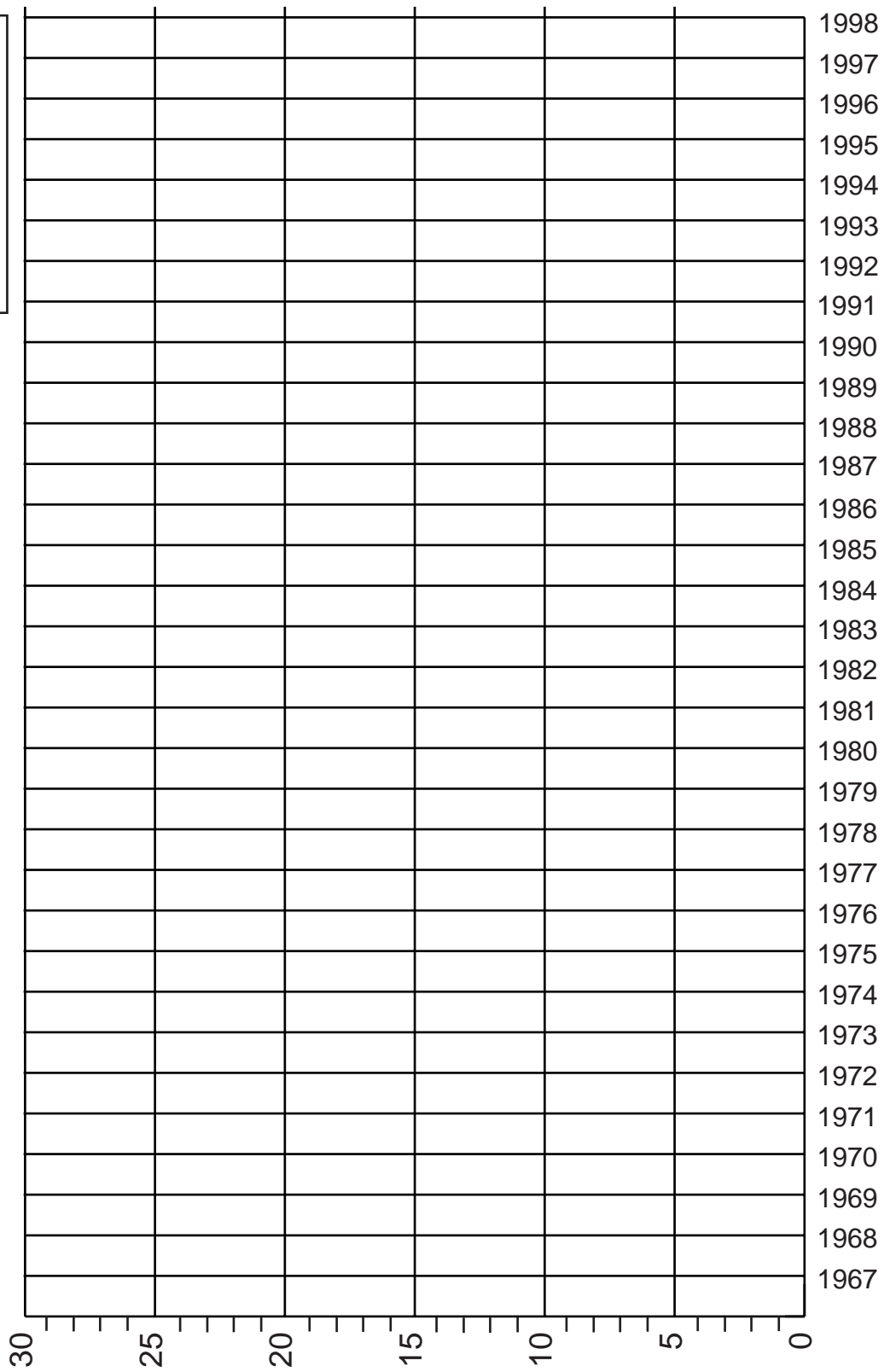
each of the 32 years of data. Repeat the process for the Middle Fork and the North Fork and the average.

- **Use a different color for each of the three lines.**
- **Be sure to mark the legend with the color representing each line.**

Student sheet

Chinook Salmon Spawning Density, John Day District, 1967-1998

Middle Fork
John Day
North Fork



Questions

1. Look carefully at the overall picture of how John Day Basin spawning fish populations have changed throughout the years. Do the peaks and valleys for each stream's line parallel each other? Describe the general trends and comparisons you see on the graph.
2. Describe any change in the pattern for the years 1977 to 1989. What has happened since 1990?
3. Which team had the lowest average redds per mile?
4. Referring to the introductory information, what human activity may have helped increase the number of redds per mile on the North Fork John Day in the late 1960s?
5. Looking at the overall trends on the graph, do you notice any changes after 1984? Describe what you see. Why do you think this is happening?
6. List as many ways as you can to describe how stream habitat restoration efforts can help increase fish populations?
7. What are the things a "stream doctor" must know to be effective in restoring a stream?

Student sheet

Clackamas carrying capacity

Activity Education Standards: Note alignment with Oregon Academic Content Standards beginning on p. 483.

Objectives

The student will (1) calculate the estimated number of steelhead smolts per mile that could survive to migrate to the ocean, (2) calculate how many smolts could be produced by the available habitat within the entire 135 miles of the Clackamas Basin, (3) calculate how many adults are needed to fill the habitat to capacity and determine the potential production of a pair of adult steelhead, (4) compare the calculated figures obtained with the actual numbers counted by researchers, and (5) suggest reasons why the calculated carrying capacity does not match the actual numbers.

Method

Students will complete a series of calculations to determine the rearing potential of the stream, compare these figures to actual counts determined by fish biologists, and draw comparisons between the two numbers.

For younger students

1. Consult extension activities at the end of each chapter to address the needs of younger students.
2. Read activity background information aloud to younger students or modify for your students' reading level.
3. Use "carrying capacity" extension activity to help younger students grasp this concept.

Vocabulary

carrying capacity

Materials

- copies of student sheets (pp. 413-418)

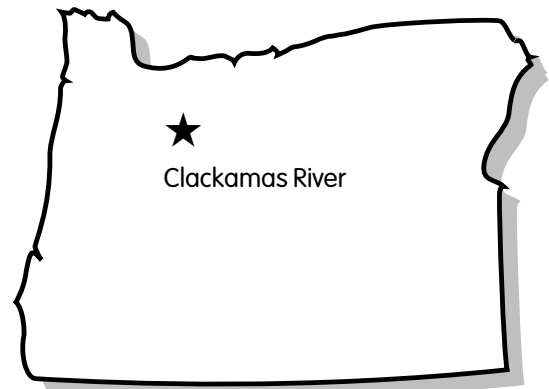
Background

Do you know . . .

Carrying capacity is the number of animals a habitat can support throughout the year without harm to either the organisms or the habitat. Factors like food, water, cover, and space limit the number of fish or other animals any specific habitat, like a stream, can support.

Carrying capacity is generally highest during the summer months when food supplies are at their peak and lowest during the winter months when food is in short supply. Carrying capacity in streams is affected by low streamflows and high water temperatures in late summer.

Fish and most other populations tend to expand to numbers their habitat (food, water, cover, and space) can support. This is true even though disease, competition, predation, parasitism, and reproductive capabilities all play a part in keeping populations down.



Activity developed by Nancy MacHugh, Oregon Department of Fish and Wildlife.

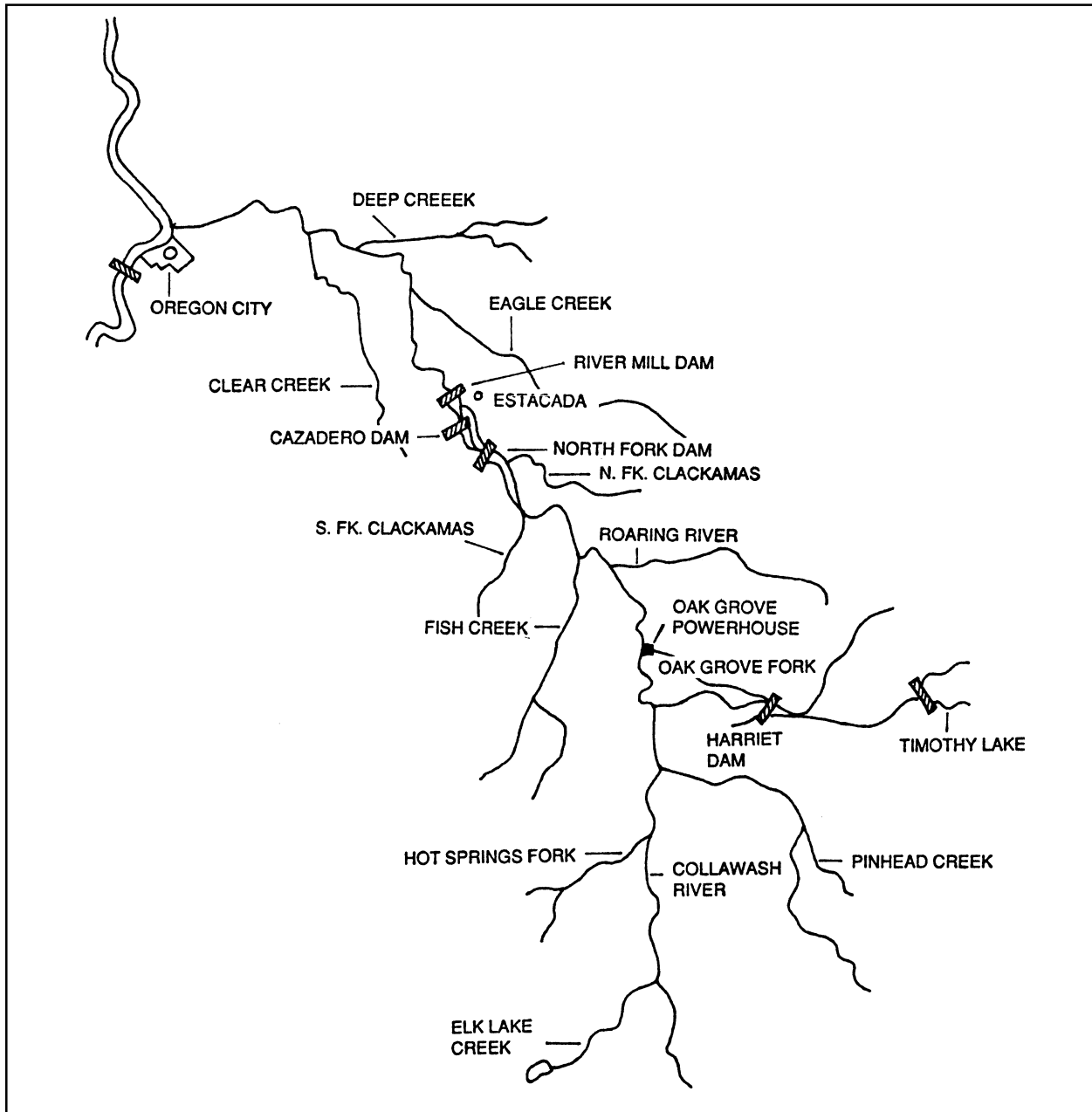
Biologists inventory fish populations throughout the year to find out how the fish are doing. For example, biologists regularly survey a few sections of the upper Clackamas River (above the North Fork Dam) and count young winter steelhead in selected tributaries and sections of the mainstem Clackamas River. Their calculations reveal an average of 1,776 yearling and older steelhead per mile of stream surveyed.

Procedure

Now it's your turn . . .

What is the carrying capacity of these surveyed sections of the Clackamas River? In this activity you will calculate the estimated carrying capacity for this stream section and compare it to actual fish counts.

Clackamas River System



Questions

1. Wild winter steelhead spend two to three years in freshwater habitats before migrating to the ocean. How many ocean-going smolts per mile would be produced and supported, based on the average listed in the introductory information, if 50% of the juveniles observed survived to migrate to the ocean?

888 smolts per mile (50% of 1,776 yearling or older steelhead per mile of survey)

North Fork Clackamas Downstream Migrants, Wild Steelhead Smolts

Year	Count
1959	36,336
1960	38,888
1961	17,694
1962	22,531
1963	24,806
1964	30,727
1965	13,858
1966	11,035
1968	31,386
1968	35,758
1969	29,187
1970	31,457
1971	19,111
1972	15,476
1973	21,403
1974	27,306
1975	28,024
1976	105,577
1977	33,792
1978	77,828
1979	41,334
1980	48,231
1981	43,558
1982	44,544
1983	31,615
1984	40,647
1985	35,152
1986	50,355

2. Surveys also showed 135 miles of the upper Clackamas Basin were used by steelhead. If all sections of the river produced steelhead at the same rate as the small number of sections surveyed, how many smolts could be expected to be produced by the entire 135 miles of stream?

119,880 smolts (135 × 1,776)

3. Using the table at the right, calculate the average number of adult winter steelhead spawning per year in the upper watershed of the Clackamas River for the period 1957-1984.

1,806 adult steelhead (add counts for 1957-1984 and divide by number of years)

4. If 50% of the adults spawning in Question 3 above are females, how many females are present?

903 females (50% of 1,806)

5. If each female places 4,500 eggs in a redd (fish nest), how many eggs would this represent?

4,063,500 eggs (903 × 4,500)

6. If only one of every 100 eggs survives to smolt age, how many smolts would be expected to survive to migrate to the ocean? (The greatest mortality in a steelhead's life cycle occurs during the egg-to-fry stages. Poor gravel conditions, inadequate oxygen, predators, and temperature extremes all take their toll on the eggs and fry.)

40,635 smolts (4,063,000 ÷ 100)

7. A count of smolts is taken as they migrate downstream through the North Fork Dam fishway. What is the average number of smolts surviving to migrate to the ocean per year (produced by the 1957-1984 adults in the questions above) based on these fishway counts? Use the 1959-1986 downstream migrant counts from the table at left. (Do not use the 1976 figure when calculating the average. A large release of smolts from a hatchery source was made in 1976. Using this figure in calculation of the average would create unrealistic expectations from the data.)

Adult Winter Steelhead Counts at PGE's North Fork Dam

Year	Count
1957	1,648
1958	566
1959	1,148
1960	2,204
1961	4,360
1962	2,257
1963	1,883
1964	1,552
1965	1,290
1966	682
1968	790
1968	2,316
1969	2,809
1970	4,349
1971	2,634
1972	1,897
1973	671
1974	1,526
1975	1,182
1976	1,527
1977	1,987
1978	1,511
1979	2,065
1980	2,697
1981	1,446
1982	1,099
1983	1,238
1984	1,225

35,272 smolts (add counts for 1959-1986, excluding 1976 and divide by number of years)

8. In Question 2 you calculated the potential number of smolts (or carrying capacity for production). What percent of those smolts does your estimate in Question 6 represent?

33.9% ($40,635 \div 119,880 \times 100$)

What percent does the actual fishway count in Question 7 represent?

29.4% ($35,272 \div 119,880 \times 100$)

9. Assuming the smolt estimate from stream surveys is reasonably accurate, does your answer to Question 8 suggest steelhead production is at capacity?

No, there is room for more production. If survival to smolt, smolt-to-adult survival, or numbers of adult steelhead returning past fishermen can be increased, more steelhead smolts could be produced.

10. If survival from egg to smolt stays at 1 in 100, how many adult steelhead would need to spawn in the Clackamas to achieve the actual carrying capacity of the 135 miles of habitat?

5,328 adults ($119,880 \times 100 = 11,988,000$ eggs, $11,988,000 \div 4,500$ eggs/female = 2,664 females $\times 2 = 5,328$ adults)

11. If, as part of a habitat enhancement project, an additional quarter mile of spawning gravel was placed in areas of the Clackamas that were previously lacking adequate spawning gravel, would the carrying capacity of this section of the river be increased? Why or why not?

Increased amounts of good quality spawning gravel would provide more habitat for spawning to occur. If more fish were able to spawn, and if rearing areas for the young fish were available, the carrying capacity of the stream could be increased. However, additional spawning gravel does not guarantee higher carrying capacity if sufficient good quality rearing areas are not available. The available habitat has a specific carrying capacity and will only support a certain number of juveniles.

Going further

1. Identify several factors in your local watershed that could affect the survival of salmon or other fish species. Hypothesize how these factors could change survival rates and calculate those change in survival over several generations.
2. Contact your local department of fish and wildlife. Volunteer to assist with fish population surveys on streams in your area. Ask the local fisheries biologist to show you how the data is collected, analyzed and presented. Prepare a report and share this information with the class.

Clackamas carrying capacity

Do you know . . .

Carrying capacity is the number of animals a habitat can support throughout the year without harm to either the organisms or the habitat. Factors like food, water, cover, and space limit the number of fish or other animals any specific habitat, like a stream, can support.

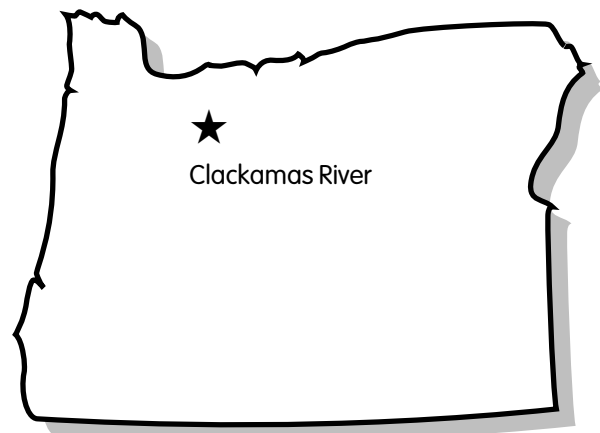
Carrying capacity is generally highest during the summer months when food supplies are at their peak and lowest during the winter months when food is in short supply. Carrying capacity in streams is affected by low streamflows and high water temperatures in late summer.

Fish and most other populations tend to expand to numbers their habitat (food, water, cover, and space) can support. This is true even though disease, competition, predation, parasitism, and reproductive capabilities all play a part in keeping populations down.

Biologists inventory fish populations throughout the year to find out how the fish are doing. For example, biologists regularly survey a few sections of the upper Clackamas River (above the North Fork Dam) and count young winter steelhead in selected tributaries and sections of the mainstem Clackamas River. Their calculations reveal an average of 1,776 yearling and older steelhead per mile of stream surveyed.

Now it's your turn . . .

What is the carrying capacity of these surveyed sections of the Clackamas River? In this activity you will calculate the estimated carrying capacity for this stream section and compare it to actual fish counts.



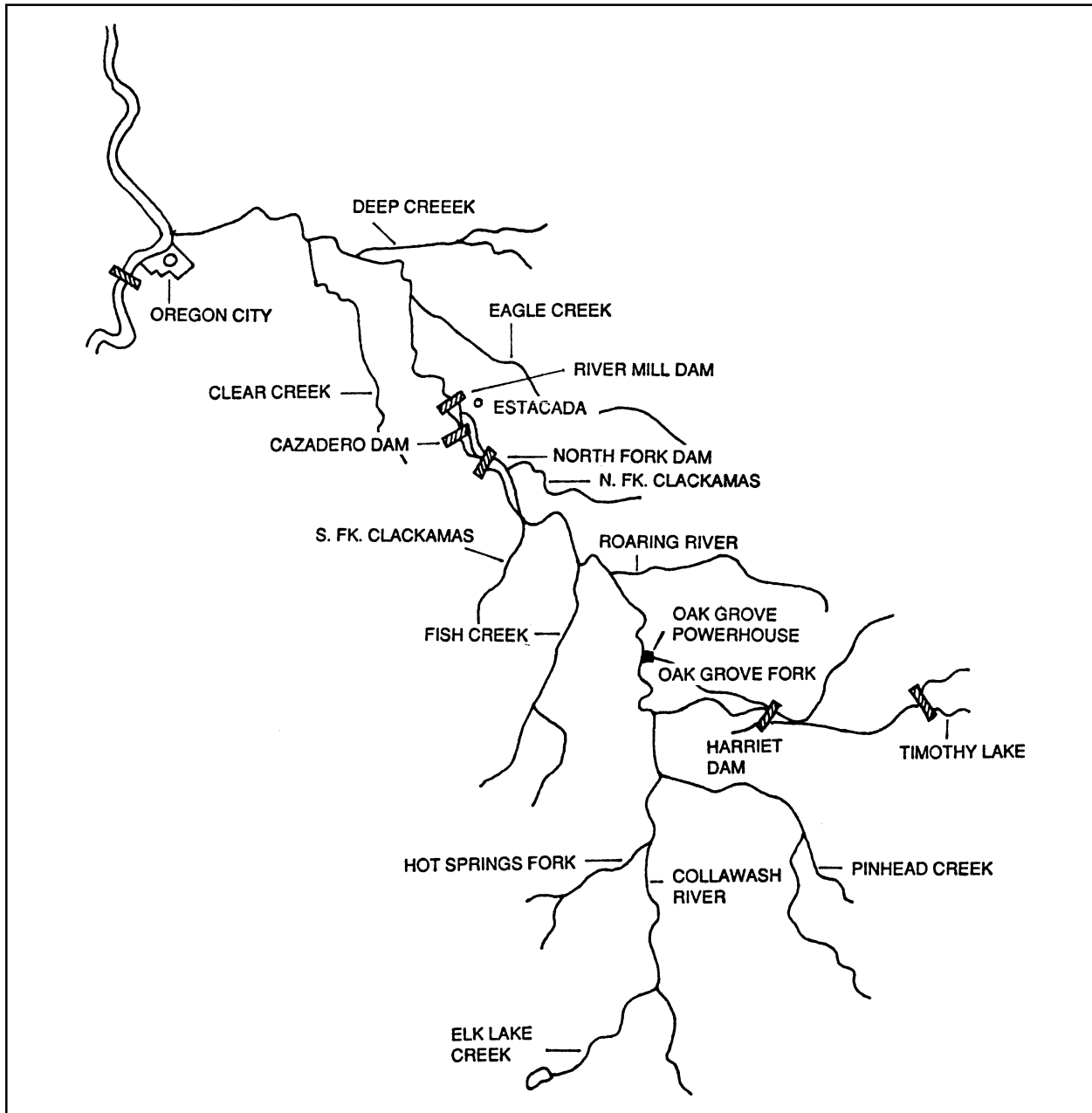
Vocabulary

carrying capacity

Activity developed by Nancy MacHugh, Oregon Department of Fish and Wildlife.

Student sheet

Clackamas River System



Student sheet

Questions

1. Wild winter steelhead spend two to three years in freshwater habitats before migrating to the ocean. How many ocean-going smolts per mile would be produced and supported, based on the average listed in the introductory information, if 50% of the juveniles observed survived to migrate to the ocean?
2. Surveys also showed 135 miles of the upper Clackamas Basin were used by steelhead. If all sections of the river produced steelhead at the same rate as the small number of sections surveyed, how many smolts could be expected to be produced by the entire 135 miles of stream?
3. Using the table at the right, calculate the average number of adult winter steelhead spawning per year in the upper watershed of the Clackamas River for the period 1957-1984.
4. If 50% of the adults spawning in Question 3 above are females, how many females are present?
5. If each female places 4,500 eggs in a redd (fish nest), how many eggs would this represent?

Adult Winter Steelhead Counts at PGE's North Fork Dam

Year	Count
1957	1,648
1958	566
1959	1,148
1960	2,204
1961	4,360
1962	2,257
1963	1,883
1964	1,552
1965	1,290
1966	682
1968	790
1968	2,316
1969	2,809
1970	4,349
1971	2,634
1972	1,897
1973	671
1974	1,526
1975	1,182
1976	1,527
1977	1,987
1978	1,511
1979	2,065
1980	2,697
1981	1,446
1982	1,099
1983	1,238
1984	1,225

6. If only one of every 100 eggs survives to smolt age, how many smolts would be expected to survive to migrate to the ocean? (The greatest mortality in a steelhead's life cycle occurs during the egg-to-fry stages. Poor gravel conditions, inadequate oxygen, predators, and temperature extremes all take their toll on the eggs and fry.)

**North Fork
Clackamas
Downstream
Migrants, Wild
Steelhead Smolts**

7. A count of smolts is taken as they migrate downstream through the North Fork Dam fishway. What is the average number of smolts surviving to migrate to the ocean per year (produced by the 1957-1984 adults in the questions above) based on these fishway counts? Use the 1959-1986 downstream migrant counts from the table above right. (*Do not use the 1976 figure when calculating the average. A large release of smolts from a hatchery source was made in 1976. Using this figure in calculation of the average would create unrealistic expectations from the data.*)

8. In Question 2 you calculated the potential number of smolts (or carrying capacity for production). What percent of those smolts does your estimate in Question 6 represent?

What percent does the actual fishway count in Question 7 represent?

Year	Count
1959	36,336
1960	38,888
1961	17,694
1962	22,531
1963	24,806
1964	30,727
1965	13,858
1966	11,035
1968	31,386
1968	35,758
1969	29,187
1970	31,457
1971	19,111
1972	15,476
1973	21,403
1974	27,306
1975	28,024
1976	105,577
1977	33,792
1978	77,828
1979	41,334
1980	48,231
1981	43,558
1982	44,544
1983	31,615
1984	40,647
1985	35,152
1986	50,355

9. Assuming the smolt estimate from stream surveys is reasonably accurate, does your answer to Question 8 suggest steelhead production is at capacity?

Student sheet

10. If survival from egg to smolt stays at 1 in 100, how many adult steelhead would need to spawn in the Clackamas to achieve the actual carrying capacity of the 135 miles of habitat?
11. If, as part of a habitat enhancement project, an additional quarter mile of spawning gravel was placed in areas of the Clackamas that were previously lacking adequate spawning gravel, would the carrying capacity of this section of the river be increased? Why or why not?

Student sheet
