In This Unit:

- A Short Course on Watersheds
- What are Salmonids?

Learning Activities

- Water-The Constant Traveler
- Finding Your Ecological Address
- Tyee's Magnificent Journey

Unit 2

Introduction to Watersheds & Salmonids

The Origin of Puget Sound and the Cascade Range

From INDIAN LEGENDS OF THE PACIFIC NORTHWEST

Ella E. Clarke, University of California Press at Berkeley, 1953

Clarence Pickernell, a Quinault-Chehalis-Cowlitz Indian from Tahola, Washington told this legend in February, 1951. He had heard it from his great-grandmother. Pickernell pronounced the closing words rapidly, in a rhythm and with a hand movement to suggest the lapping of water against the shore.

One time when the world was young, the land west of where the Cascade Mountains now stand became very dry. This was in the early days before rains came to the earth. In the beginning of the world, moisture came up through the ground, but for some reason, it stopped coming. Plants and trees withered and died. There were no roots and no berries for food and water in the streams became so low that salmon could no longer live there. The ancient people were hungry. At last, they sent a group of their people westward to ask Ocean for water.

"Our land is drying up," they told him. "Send us water lest we starve and die."

"I will send you my sons and daughters," Ocean promised the ancient people. "They will help you."

Ocean's sons and daughters were Clouds and Rain. They went home with the messengers from the dry country. Soon there was plenty of moisture. Plants and trees became green and grew again. Streams flowed with water, and many fish lived in them again. Roots and berries grew everywhere.. There was plenty to eat.

But the people were not satisfied with plenty. They wanted more. They wanted to be sure they would always have water. So they dug great pits and asked Clouds and Rain to fill them.

Clouds and Rain stayed away from their father, Ocean, so long that he became lonely for them. After many moons, he sent messengers to ask that his sons and daughters be allowed to come home.

"Let my children return home," he sent word to the ancient people. "You have enough water for the present, and I will see that you have enough in the future."

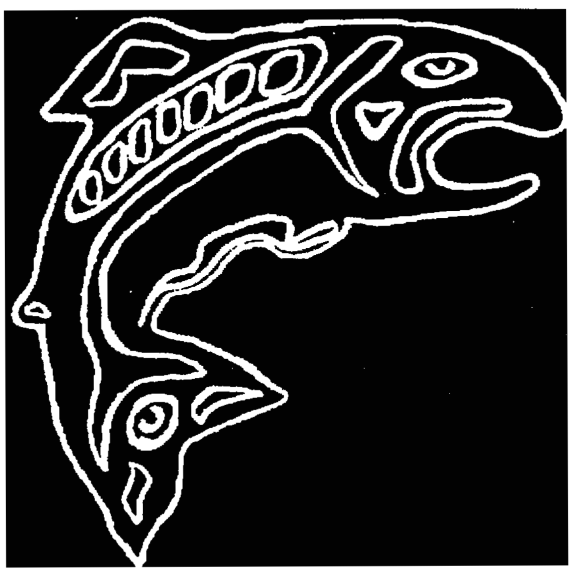
But the people were selfish and refused to let Clouds and Rain go. The messengers had to return to Ocean without his sons and daughters. The Ocean told his troubles to the Great Spirit.

"Punish the people for their evil ways," prayed Ocean. "Punish them for always wanting more and more."

The Great Spirit heard his prayer. He leaned down from the sky, scooped up a great amount of earth, and made the Cascade Mountains as a wall between Ocean and the dry country. The long and deep hole left where the earth had been, Ocean soon filled with water. Today, people call it Puget Sound.

The people east of the mountains are still punished for their selfishness and greed. Ocean sends so little moisture over the range that they do not have all of the plants that grow along the coast. But they still have the pits their grandfathers dug. They are Lake Chelan and the lakes south and east of it.

Ocean still grieves for his sons and daughters who did not come home. All day and all night along the beach he calls to them and sings their mournful song: "Ab'tab lab' tab lab'! Ab tab lab'! Ab tab lab' tab lab' Come Home! Come Home!"



A Short Course on Watersheds

(Background information for learning activities "Water - The Constant Traveler," p. 89 and "Finding Your Ecological Address," p.95)

All land on earth is a watershed. Humans and their activities play an important and essential role in watersheds, yet few people understand them. Still fewer know the dynamics and boundaries of the watersheds in which they live.

If you were to stand in a stream bed and look upstream at all the land the stream drains, you would be looking at the stream's watershed. Almost all the area of a watershed is land, not water. And almost everything that influences the stream's ecological health occurs on that land.

A river and its branching collector streams stretch through a watershed area and gather water along their way, collecting particulates and pollution from a variety of activities on land. Understanding this process is key to an awareness of how human actions affect water quality as well as fish, wildlife, and the natural processes within a watershed area. When students are able to perceive (in a concrete way) the connectedness of all the living things within their watershed, they can begin to develop a sense of ecological responsibility.

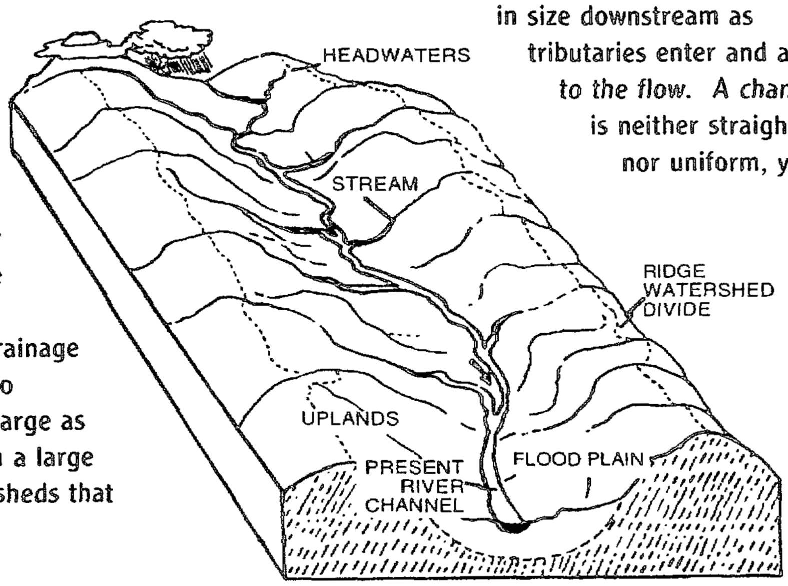
A watershed is a system. It is the land area from which water, sediment, and dissolved materials drain to a common watercourse or body of water. For each watershed there is a drainage system that conveys rainfall to its outlet. A watershed may be the drainage area surrounding a lake that has no surface outlet, or a river basin as large as that of the Columbia River. Within a large watershed are many smaller watersheds that contribute to overall streamflow.

The border between two watersheds is called a divide. A watershed is drained by a network of channels that increase in size as the amount of water and sediment they must carry increases.

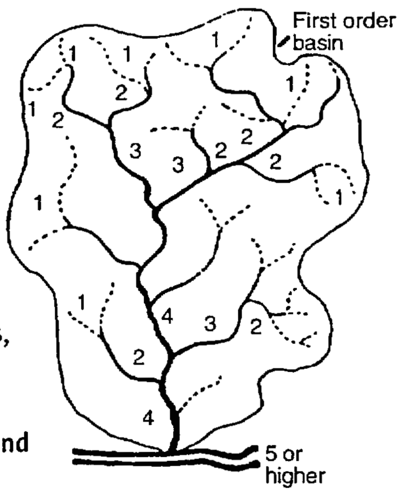
Streams are dynamic, open-water systems with channels that collect and convey surface runoff generated by rainfall, snowmelt, or groundwater to the estuaries and oceans. The shape and pattern of a stream is a result of the land it is cutting and the sediment it must carry.

Stream Orders

In most cases, a watershed system is almost entirely hillside. Only about one percent of a watershed is stream channel. The smallest channels in a watershed have no tributaries and are called first-order streams. When two first-order streams join, they form a second-order stream. When two second-order channels join, a third-order stream is formed, and so on. First - and second-order channels are often small, steep, or intermittent. Orders six or greater are larger rivers. Channels change by erosion and deposition. Natural channels of rivers increase in size downstream as tributaries enter and add to the flow. A channel is neither straight nor uniform, yet



progressive fashion. In upstream reaches, the channel tends to be steeper. Gradient decreases downstream as width and depth increase. The size of sediments tends to decrease, often from boulders in the hilly or mountainous upstream portions, to cobbles or pebbles in middle reaches. More sand or silt are found downstream. In some cases, large floods cause new channels to form, leaving once-productive streams dry and barren.



Streamflow Types

Besides the ordering system previously described, streams may be classified by the period of time during which flow occurs.

- ◆ Perennial flow indicates a nearly year-round flow (90 percent or more) in a well-defined channel. Most higher order streams are perennial.

- ◆ Intermittent flow generally occurs only during the wet season (50 percent of the time or less).

- ◆ The physical, chemical, and biological makeup of a stream relates to surrounding physical features of the watershed and geologic origin. Analysis of these features aids understanding of stream-watershed relationships and predicts effects of human influences on different stream types.

Factors Affecting Watersheds

Climate

Land and water are linked directly by the water cycle. Solar energy drives this and other cycles in the watershed. Climate - the type of weather a region has over a long period of time - is the source of water. Water comes to the watershed in seasonal cycles, principally as rain or snow. In some areas, condensation and fogdrip contribute water. The seasonal pattern of precipitation and temperature variation control streamflow and water production.

Some precipitation infiltrates the soil and percolates through permeable rock into groundwater storage and recharges areas called aquifers. Natural ground water discharge is the main contributor to streamflow during dry summer and fall months. Without groundwater discharge, many streams would dry up.

Land and water are linked directly by the water cycle.

Pumping water from an aquifer for industrial, irrigation, or domestic use reduces the aquifer's volume. Unless withdrawals are modified or recharge increased, the aquifer will eventually be depleted. A drained aquifer can collapse from the settling of the overlying lands.

Collapsed underground aquifers no longer have as much capacity to accept and hold water. Recharge is difficult, volume is less, and yields are considerably reduced. Springs once fed from the water table also dry up.

Climate affects water loss from a watershed as well as providing water. In hot, dry, or windy weather, evaporation loss from bare soil and water surfaces is high.

The same climatic influences that increase evaporation also increase transpiration from plants. Transpiration draws on soil moisture from a greater depth than evaporation because plant roots may reach into available moisture supply. Transpiration is greatest during the growing season and least during cold weather when most plants are relatively dormant.

Wind may cause erosion, control the accumulation of snow in sheltered places, and may be a significant factor in snowpack melting. Wind erosion can occur wherever wind is strong and constant, or where soil is unprotected by sufficient plant cover.

Physical features

It is not surprising that the size of a watershed affects the amount of water in it. Generally, a large watershed receives more precipitation than a small one, although greater precipitation and runoff may occur on a smaller watershed in a moist climate than on a large watershed in an arid climate.

Shape and slope of a watershed and its drainage pattern influence surface runoff and seepage in streams draining the watershed. The steeper the slope, the greater the possibility for rapid runoff and erosion. Plant cover is more difficult to establish and infiltration of surface water is reduced on steep slopes.

Orientation of a watershed relative to the direction of storm movement also affects runoff and peak flows. A rainstorm moving up a watershed from the mouth releases water in such a way that runoff from the lower section has passed its peak before runoff from the higher sections has arrived. A storm starting at the top and moving down a watershed can reverse the process.

The area of a watershed affects the amount of water produced

Orientation of a watershed relative to sun position affects temperature, evaporation, and transpiration. Soil moisture is more rapidly lost by evaporation and transpiration on steep slopes facing the sun. Watersheds sloping away from the sun are cooler, and evaporation and transpiration are less.

Slopes exposed to the sun usually support different plants than those facing away from the sun. Orientation with regard to the prevailing winds has similar effects.

Soils and geology

Soil is a thin layer of the earth's crust. It is composed of mineral particles of all sizes and varying amounts of organic materials. It is formed from breakdown of parent rocks to fine mineral particles. This occurs by:

- Freezing and thawing in winter
- Heating expansion and cooling contraction in summer
- Wind and water erosion
- The grinding action of ice
- Gravity rockfall and avalanche movement
- Rock minerals in rain and snowmelt water
- Chemical action of lichens and other plants

Soils are of two types. Residual soils are those developed in place from underlying rock formations and surface plant cover. Transported soils include those transported by gravity, wind or water. Characteristics of residual soils are closely related to the parent material from which they were formed.

Climate, particularly precipitation and temperature, strongly affects soil formation. Rainfall causes leaching - movement of dissolved particles through soil by water. Temperature affects both mechanical breakdown of rocks and breakdown of organic material. Soil bacteria, insects, and burrowing animals also play a part in breakdown and mixing of soil components.

Soil often determines which plants will

Soil is the basic watershed resource . . . to be carefully managed and protected

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establish a protective vegetative cover. Plants also modify and develop soil. Plant roots create soil spaces. Plant litter adds organic matter to soil and extracts water and minerals in solution through the roots. Plant litter slows surface runoff and protects the soil surface from rainfall's beating and puddling effects. Soil depths and moisture-holding capacities are usually less on steep slopes, and plant growth rates are slower.

Forage, timber, and water are all renewable resources. Water is renewed by cycles of climate. Forage and timber are renewed by growth in seasonal cycles. The availability of these resources is dependent upon soil. Soil is, except over long periods, a non-renewable resource. It may take more than a century to produce a centimeter of soil and thousands of years to produce enough soil to support a high-yield, high-quality forest, range, or agricultural crop. Soil is the basic watershed resource. Careful management and protection is necessary to preserve its function and productivity.

Vegetative cover

Grasses, forbs, shrubs and trees make up the major plant cover types. All four types build up organic litter and affect soil development. They usually develop under differing climatic conditions and all are important to watershed management.

A forest usually includes, in addition to trees in various stages of growth, an understory of shrubs and a low ground cover of forbs and grasses. While all plants in a forest have some effect on water, trees are the most important. Tree-litter fall protects the soil's surface. Tree roots go deep into the soil and help bind it, and tree crowns provide the most shade. The effects of shrubs and grasses are similar to those of trees including increased protection for soil against the beating action of rain and drying action of the wind.

Plant cover benefits a watershed. The canopy intercepts rain and reduces the force with which it strikes the ground. The canopy and stems also reduce wind velocity.

When leaves and twigs fall, they produce litter, which decomposes and is eventually incorporated into the soil. Litter protects the soil surface, allows infiltration and slows down surface runoff. Stems and roots lead water into the ground. Roots

open up soil spaces for water retention and drainage as well as add organic materials to the soil. The movement of minerals from roots to canopy provides recycling.

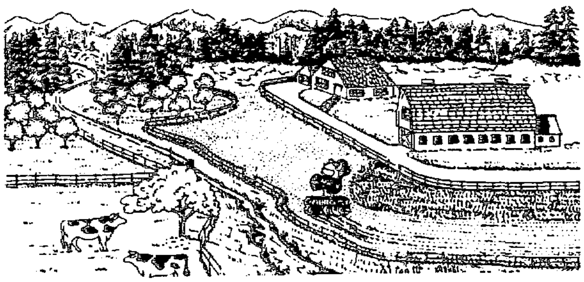
Windbreaks of trees and shrubs protect crops and reduce moisture losses from evaporation. Grasses, trees, and shrub stems along riverbanks trap sediments and floating debris during high waterflows. Roots bind and stabilize streambanks and slopes to reduce slides and slumps. While all plants in a forest have some effect on water, trees are the most important.

Management Considerations

Water quality is largely determined by the soils and vegetation in a surrounding watershed. Accordingly, human activities have pronounced impacts on watershed quality. These activities include timber harvesting, livestock grazing, agriculture, recreation and urban or industrial development.

Timber Harvest

Timber harvest opens and reduces plant cover density. Timber harvest does not negatively affect



a watershed if slope and soil are carefully considered and plant cover rapidly restored. In snow zones, timber harvest can improve snow catch and modify snowmelt rate. Washington and several other states have passed laws called Forest Practices Acts to ensure consideration of soil and water resources during timber harvest.

Agriculture

Domestic livestock tend to concentrate in specific areas when grazing. Concentrated grazing impacts plant cover and soil. Grass cover can be improved by removing some of the annual growth, but forage productivity can be greatly reduced if overgrazing occurs. Improperly timed grazing, grazing too many animals, or grazing for too long a time can change vegetation over a period of years to species of lower value. Overuse of rangelands by native grazing animals can also seriously damage plant cover.

Excessive trampling by grazing animals can contribute to soil compaction, accelerated runoff, and erosion problems. Trampling can also help scatter seeds and incorporate them into the soil for regeneration.

Management of livestock and grazing wildlife species can enhance watershed values, but is limited by the carrying capacities of the land and the forage species it will support. Management must consider timing, density and duration of animal use to capitalize on the positive aspects of grazing. Generally, recovery does not occur if vegetation is thinned to less than 70 percent of the natural cover. Without management practices such as reseeding, degradation will continue.

Crop production usually involves removal of the original plant cover and tilling the soil for seedbed preparations. Crop cover is usually seasonal and less dense than natural cover. This provides less protection for the soil. Erosion by both wind and water may remove the finer and more fertile soil particles, reducing land productivity. Agricultural operations based on careful appraisal of soil, slope, and climatic conditions include erosion control and are compatible with watershed management.

Plant cover affects water through growth and transpiration. Shade and mulch formed by plant litter reduce evaporation of soil moisture. Plant roots can take up available soil moisture to a greater depth than evaporation.

An example is accelerated brush encroachment, particularly juniper, on central and eastern Washington uplands. Increased juniper stands have, in part, decreased summer streamflows. Juniper competes more successfully than other vegetation for available moisture. This reduces ground cover and may cause increased runoff and less infiltration to groundwater storage. In addition, juniper roots can tap groundwater storage. Juniper's high transpiration rate leaves less water for stream runoff as summer progresses.

Fire

Fire is one of the most widespread and destructive agents affecting plant cover. Under certain conditions, fire can nearly remove cover and organic litter, and, in extreme cases, sterilize and change the chemistry of the surface soil.

Fire is one of the most widespread and destructive agents affecting plant cover. Fire can also be beneficial to a watershed when it is managed

Burning converts organic materials in plant cover, litter, and topsoil to gases and soluble, readily leached ashes that can make acid soils alkaline. Damage to soil varies, but it may take several seasons for soil conditions to return to normal.

Without a protective canopy and litter, the soil surface is rapidly puddled and sealed by the first rains. Infiltration is greatly reduced, making runoff and erosion more rapid. Debris-laden floods often occur within fire-denuded watersheds during only slightly abnormal rainfall. Most of the water falling on a burned landscape is lost by rapid runoff. Water that infiltrates is probably lost by evaporation.

Streams from burned watersheds at first carry a heavy load of salts dissolved from ashes, floating debris, and erosion sediments. Water quality may soon return to normal, except for sediment-laden high flows. Water levels fluctuate and become less dependable. These conditions may continue for several years until the plant cover becomes reestablished on the watershed.

Fire can be beneficial to a watershed when it is carefully managed. It can reduce available fuel and prevent more destructive fires. Fire thins understory seedlings that compete with larger trees for available moisture. Open forest types such as ponderosa pine are maintained by fire.

Beavers

The effects of beavers on a watershed can be both positive and negative. Their actions change watershed hydrology as well as damage cover. A beaver dam changes energy flow in its immediate area by turning part of a stream environment into a pond or swamp. If high beaver populations coincide with heavy livestock use, the results can be devastating to streams. On the other hand, their dams can be beneficial as sediment traps and fish habitat. Water held behind a beaver dam is released more slowly over a longer period of time.

Mining

Mining requires opening the earth to remove mineral resources. It is done by stripping off the surface soil and rock layers or by drilling tunnels into the earth to reach minerals.

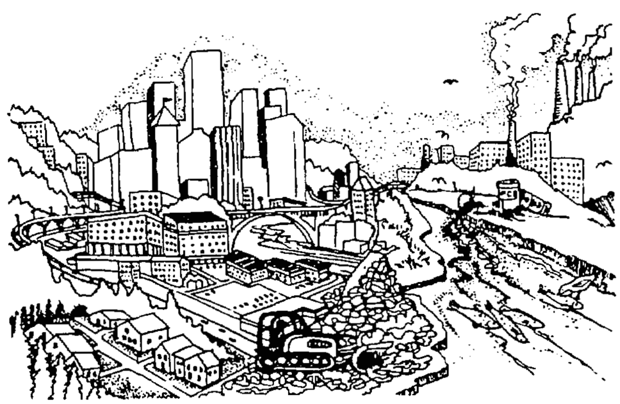
With either method, quantities of waste material are left on the surrounding land. This waste material is subject to erosion, adding to the sediment load of streams draining the mined area. Surface changes include altered topography and drainage. Drainage from mined areas may contain toxic mineral salts harmful to the aquatic habitat. To prevent degradation of the watershed, waste material disposal must be controlled.

Development

Urban development involves:

- Clearing, leveling and filling land surfaces
- Constructing buildings with impermeable roofs
- Paving roads and sidewalks with impervious materials
- Installing sewage disposal systems

Such development greatly changes infiltration



and runoff, reduces recharge to underground water and increases runoff to produce rapidly fluctuating streamflows.

High-quality water is described as cool, clear, clean, colorless, odorless, tasteless, oxygenated, free of floating and suspended materials, and carrying only limited amounts of dissolved materials. As quality is degraded, water becomes less and less useful for most purposes. Urbanization decreases water quality. Point source pollutants enter waterways from a specific point. Common point source pollutants are discharges from factories and municipal sewage treatment plants. This pollution is relatively easy to collect and treat.

Most municipal wastewater treatment facilities, like Seattle Public Utilities, use secondary treatment to remove waste materials biologically. Oxygenation and enhanced growing conditions are provided for bacteria and other organisms which break down dissolved organic materials in wastewater. Secondary treatment removes 85-90% of suspended solids and eliminates almost all disease bacteria.

Non-point source pollution is really a new name for an old problem - runoff and sedimentation. Non-point source pollution runs off or seeps from broad land areas as a direct result of land use. It comes from a variety of sources such as agriculture, urban construction, residential developments, timber harvest, roadsides, and parking lots. Sediment, fertilizers, toxic materials, and animal wastes are major non-point source pollutants. The diffuse source of these pollutants makes them more difficult to quantify and control than point source pollutants.

Non-point pollution causes more than half the water pollution problems in Washington. The impact of non-point source pollutants on water quality is variable. Some are potential health hazards or harmful to fish and other aquatic organisms. Streams do have an absorption and disposal capacity for limited amounts of pollutants, but these limits are too often exceeded.

Urban air pollution, especially photochemical smog caused by internal combustion gasoline engine emissions and industrial smokes, has contributed to acid rain. This has had an effect on vegetation, streams, and lakes within watersheds, especially on the east coast and in Canada. The problem continues to grow, and the Pacific Northwest is not immune to the effects of acid rain.

Non-point pollution causes more than half of the water pollution in Washington

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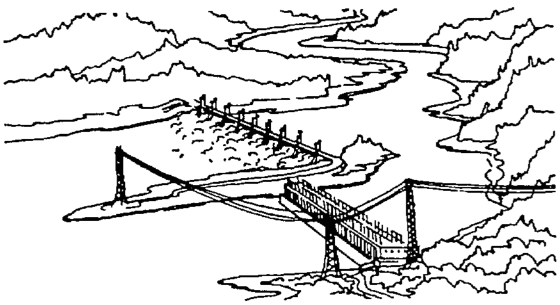
Communication and transportation developments include roads, railroads, airports, power lines and pipelines. All of these may involve disturbance of plant cover, soil, and topography. Road and highway networks, with their impermeable paving and rapid drainage systems may radically change the runoff characteristics of their immediate area. They also require changing the natural topography and drainage, and moving huge amounts of soil and rock. Often these networks are responsible for extensive sediment production and may become the source of other water pollutants.

Railroads and airports have similar effects. Power lines and pipelines require open paths through the watershed and access roads for construction and maintenance.

Impoundments

Flood control dams, lined stream channels, dikes and levees to restrict the spread of floodwaters, and channel bed stabilization techniques are all installations that modify channel capacity as well as the rate and volume of streamflow. All are the consequence of human efforts to modify water yields to better meet seasonal needs.

Many dams are built and operated to be multipurpose. They:



- Control floods
- Store water for irrigation or other consumptive use
- Regulate flow for navigation
- Provide power generation

Effects on streamflow and aquatic habitat are similar regardless of purpose. Impoundments, if shallow, allow water to warm, and, if deep, preserve cooler water.

As streamflow peaks are reduced and low flows increased, streamflow generally becomes more regular from season to season and year to year regardless of climatic variations. In many cases, reservoirs have added water-based recreation and new fisheries, although their construction may have destroyed stream habitat used by wild fish. A watershed under good management - where water storage occurs in the soils and riparian areas - lessens the need for reservoirs, particularly small headwater impoundments.

Water is often seasonally diverted from impoundments and streams for irrigation in agricultural areas. This reduces streamflows during the warm growing season. Some water is returned to the stream by drainage from the irrigated fields. These return flows are warmed and may contain soil salts, fertilizers, and pesticides leached from the fields.

Management objectives

The objective of managing a watershed is to maintain a useful vegetative cover and soil characteristics beneficial to regulation of a quality water yield. The usefulness and productivity of the land will be enhanced for other resources and uses. Rivers, hillsides, mountaintops, and flood-formed bottom-lands are all part of one system.

When the non-renewable soil resource is protected and maintained in good condition, the dependent renewable resources, wildlife habitat, and recreational opportunities can be supported.

Timber, forage, minerals, food, and wildlife represent important considerations. Problems arise when development and use of these resources conflict with the primary objective of regulating water yield and maintaining water quality and watershed integrity. These must be considered as part of watershed management, and their use and development must be integrated with management that produces and protects water supplies.

Ownership is the principal institutional control of watersheds. A private individual or public management agency may be free to apply whatever measures believed necessary or desirable on their own land. They may regulate access and prevent use and development of associated resources.

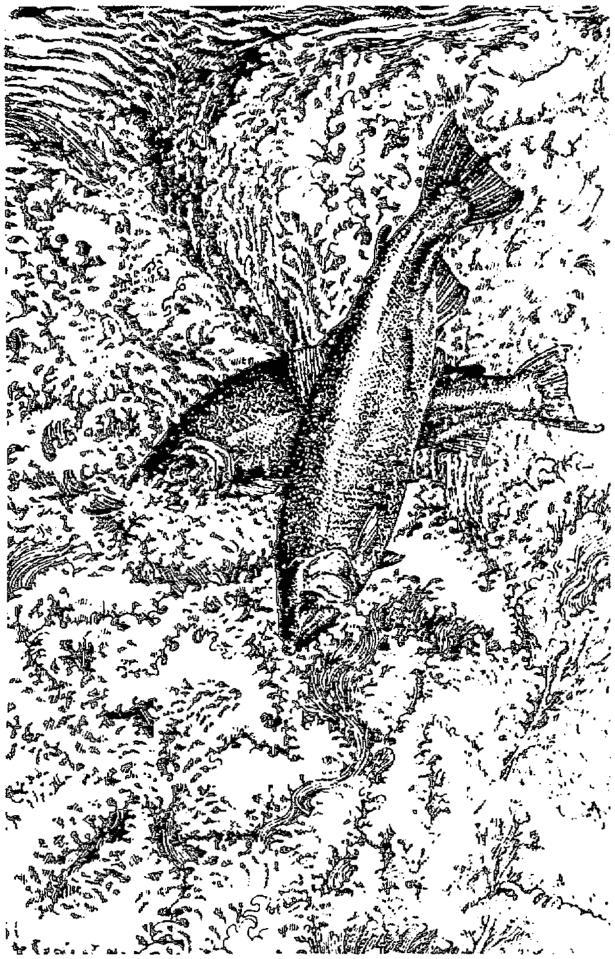
Many watersheds are in public or state ownership. Unless segregated and protected by specific legislation or agreement, most are used and developed to take advantage of all resources available for the general public benefit. It is in these multiple-use watersheds that management may face the most serious conflicts and challenges. Here it becomes necessary to attain a balanced use and development to provide maximum benefits with the least disruption of the water resource.

Legislation and government edicts also provide controls that can aid water resource management. These laws may include:

- Land Use Planning
- Zoning
- Permitted and prohibited land uses or types of development

- Restrictions on water use
- Limitations on water development
- Pollution control

Watershed users need to be aware that private actions have public consequences on water quality and quantity.



Summary

Rivers, hillsides, mountaintops, and flood-formed bottom-lands are all part of one system. All are integrated with each other. Hillside shape controls the energy expenditure rate of water flow. All biotic elements in the watershed interact with and modify the energy flow through the system. So it follows that the shape of the watershed is a function of what lives there. The combination of climatic conditions, soil types, topography, vegetative cover, and drainage system define the particular character of each watershed.

In an unaltered state, a watershed is in a state of equilibrium. This equilibrium may or may not be the most suitable for the overall quality and contribution of the watershed to the entire picture.

Rivers and seas do not stop at state lines or international boundaries. The effects of natural and human processes in a watershed are focused at its outlet, wherever it may be, even if it crosses another state or country's borders. Each watershed is a part of a larger watershed whose downstream portion may suffer from upstream influences.

What are Salmonids

(Background information for learning activities "Tyee's Magnificent Journey," p. 109)

another state or country's borders. Each watershed is a part of a larger watershed whose downstream portion may suffer from upstream influences.

Salmon and trout are part of a group of fish known as salmonids. They are a valuable biological, cultural, historical, recreational, and economic resource for Washington and the entire Pacific Northwest.

Some species of salmonids are anadromous, migrating to the ocean and back during their life cycle, while others live their entire lives in streams and landlocked lakes.

Washington has five species of Pacific salmon - chinook, chum, coho, pink, & sockeye salmon*; three trout species closely related to the salmon (in the same genus as salmon) - cutthroat trout, golden trout & rainbow trout**; One species of

Atlantic salmon closely related to the brown trout have also been introduced to some Washington lakes, and a landlocked variety of sockeye salmon [called kokanee] is also found in Washington.

Of the trout species, only steelhead rainbow trout and sea-run cutthroat trout are anadromous. These anadromous trout do not always die after spawning, often returning to the ocean and living to spawn again.

Washington has:

Five species of <u>Pacific salmon</u>

chinook

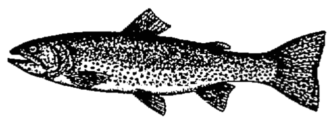
chum

coho

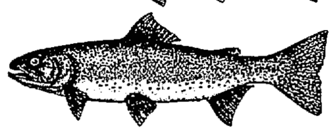
pink

sockeye

Three trout species <u>closely related to salmon</u>



rainbow

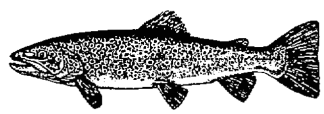


cutthroat

golden

One species of <u>true trout</u>

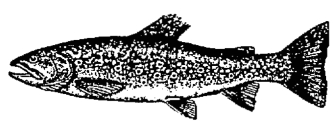
brown



Four species of <u>char</u>

bull

Dolly Varden



brook

lake

Salmonids developed during the Miocene era.

Miocene
Geologic
Age

10,000
Years
Ago

Pacific Salmon are separated from the Atlantic Ocean during the ice age.

Man begins to widely exploit natural resources, and salmonid populations decline dramatically.

100
Years
Ago

Today

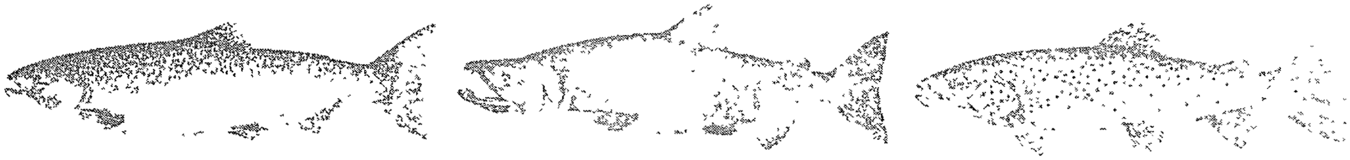
Some species of salmon are threatened with extinction

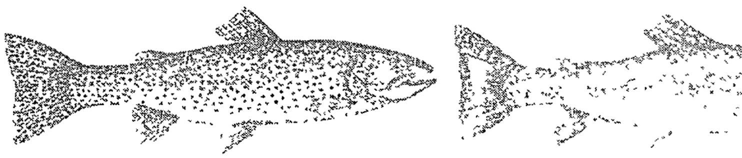
Salmonids date back to the *Miocene* geologic era, and evolved in the cold, oxygen-rich waters of the northern hemisphere. The unique migratory behavior is believed to have originated over 10,000 years ago as a result of the advancement and receding of the continental ice sheets. It was about this time period that the Pacific salmon became separated from the parent salmon stocks in the Atlantic, and as the great glaciers of the *Ice Age* melted, safe places for *spawning* and *rearing* were revealed.

Until the recent century, salmonid populations were not greatly impacted by human populations or activities. Thousands of *tributary* creeks and rivers of the Northwest teemed with salmon and trout. Over the past 100 years, *exploitation* of natural resources, including detrimental side effects of technology, have contributed to a dramatic decline of salmonid populations. The first fish hatcheries were built to make up for this decline. Today, some species of salmon are threatened with *extinction.*

Washington *hatcheries* raise rainbow, golden, cutthroat, brook, and brown trout as well as winter and summer* steelhead, spring and fall* chinook, chum, coho, kokanee, and Atlantic salmon.

**Spring and fall chinook and winter and summer steelhead are distinguished from each other based on the different seasons they arrive in freshwater on their way to the spawning grounds.*





Learning Activities

- Water-The Constant Traveler
- Finding Your Ecological Address
- Tyee's Magnificent Journey

Unit 2

Introduction to Watersheds & Salmonids

UNIT 2

WATER: THE CONSTANT TRAVELER

Portions of this activity were adapted from:
The Stream Scene
Watersheds, Wildlife and People
by Patty (Farthing) Bowers et al
Oregon Department of Fish and Wildlife
1990

For more information contact:
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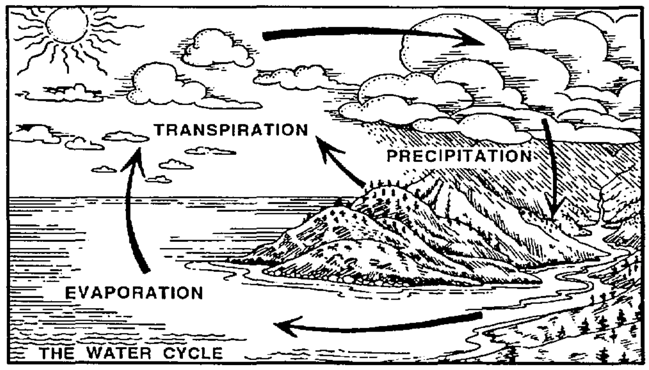


Key Concepts:

- Water travels through an earth system called the water cycle.
- The water cycle has many paths for water to follow through the system.
- The water cycle is powered by the sun and the ocean is the cycle's reservoir.

Teaching Information

Water is the priceless resource upon which all growing things depend. Water covers about three-quarters of the earth's surface. Of this, only a small amount is fresh water, less than one-third of which is usable by humans. The rest is locked in the polar ice caps and in glaciers.

Water is continually recycled and transported by the water or hydrologic cycle. The energy for driving this cycle comes from the sun. Water is moved into the atmosphere through evaporation or plant transpiration. This atmospheric vapor is transported by wind, condensed into clouds, and then returned to the earth as precipitation. It is estimated that every nine to 12 days, all moisture in the atmosphere falls to earth, making water our most recycled resource.

The water cycle is the foundation for examining water in any form. While this process transports and purifies water, its effectiveness may be reduced by such factors as vegetation removal (reducing transpiration) and atmospheric pollution (adding contaminants to otherwise pure vapor).

In Washington, moisture-laden clouds move inland from the Pacific Ocean. As clouds rise over the Olympic Mountains and coast range, their water vapor cools, condenses into drops, and falls as rain. Precipitation continues as the clouds move east, leaving more moisture as they rise over the Cascade Range. Since the Cascades intercept most of the precipitation, a rain-shadow effect is created in eastern Washington, making it more arid than the western part. Until the clouds reach the Blue, Kettle River, Selkirk, and other distinct mountain ranges, they are no longer forced to climb into cooler air, and the amount of rainfall drops dramatically.

The short reading and questions are designed to be done by students on their own, as preliminary work for discussion and the rest of Unit One. However, students could benefit from working with it in small groups or even as a class. The water cycle diagrams could also be completed in groups or individually.

Materials

Student handout

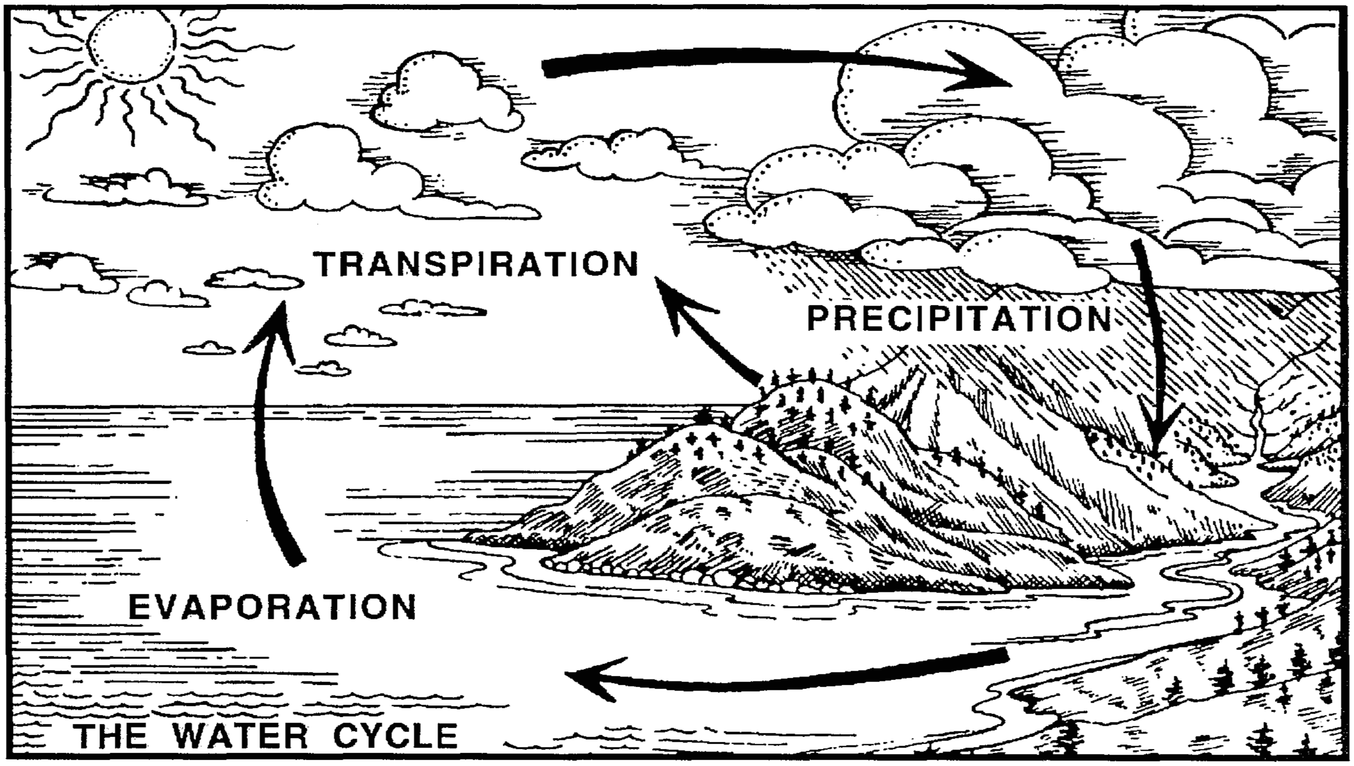
Extensions

1. Set up a standard distillation apparatus in which students can observe evaporation and condensation of water. Most basic science books describe how this can be done.
2. The following activities from Project WILD:
   - "How Wet is Our Planet?" Aquatic Project WILD
   - "Where Does Water Go After School?" Aquatic Project WILD
   - "Water's Going On?!" Project WILD.

Key Words:

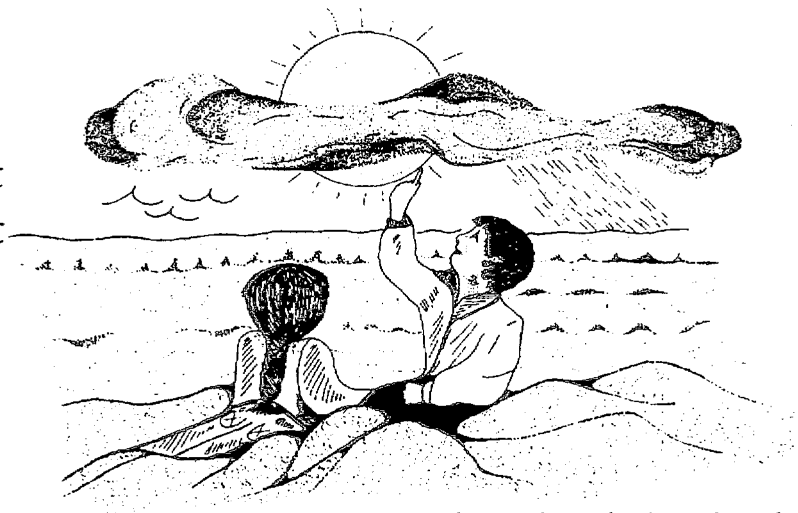
cycle; evaporate; ground water

Answer Key



Water in the ocean is heated by the *sun.* When the water has taken in enough energy (heat), it will *evaporate* and rise into the *air* (just like heating it in a pan). As it rises, the water cools, condenses, and turns into *clouds.* When the clouds hold enough water it will probably *rain* or *snow.*

Water the Constant Traveler
Student Reading



Have you ever seen the ocean? It's so big, you can't think about it with just one thought. It takes lots of thoughts to take it all in.

Sarah and her little brother Mario saw the ocean for the first time today. After looking at it for a long time, Mario said, "Where does all the water come from? It must take a lot to fill it up!"

"It must come from rivers and streams." answered Sarah.

"And where does the water come from to fill the rivers and streams?" replied Mario. "Oh, from rain!" he said, before Sarah could answer.

"And snow too." Sarah added.

"O.K. What about the rain and snow? The water to make them falls from the sky. Where does that water come from?"

This was a harder question. They both looked up at the bright, white fluffy clouds and blue sky.

"When it rains," reasoned Mario," the rain seems to come from the clouds. But there are clouds now, and it isn't raining. So, only some clouds have water in them."

"Rain clouds are darker, sort of gray and dark blue." replied Sarah, still thinking about where the water for rain and snow comes from.

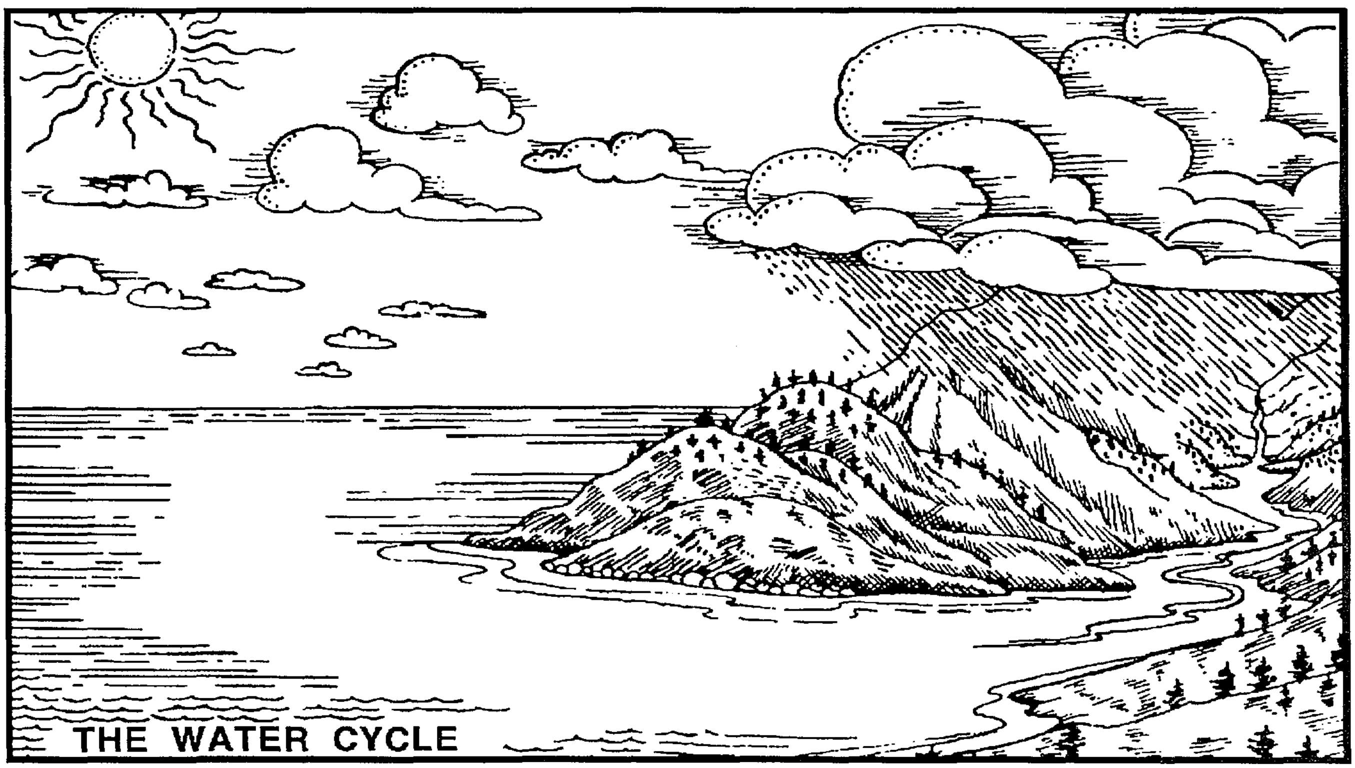
"I think the clouds ARE water. Just like fog. And when there's enough water in the clouds, it rains. Or if it's cold enough, it snows."

"Where does the water come from to make clouds?" questioned Mario. Sarah was getting a little tired of answering her brother's questions, so her answer was a little sharp. "From the sun!" She really didn't know the answer either. Do you?

COMPLETING THE WATER CYCLE

You can help Mario and Sarah solve the mystery of the water cycle. Here's how: Using the drawing below, draw arrows from the place the water comes from to the place it goes. Use the previous story for clues. Then, try to figure out where the water comes from that makes clouds.

HINT: Have you ever seen steam rising over a pan of boiling water? The heat from the stove burner heats the water until steam is produced. The water would all be turned into steam if it was heated for a long time. The steam goes into the air. Now, think back about the big ocean. Is anything heating it up? If water gets enough energy, it does a surprising thing. Fill in the blanks on the next page:



Water in the ocean is heated by the ____________________.
When the water has taken in enough energy, it will
______________ and rise into the _________________. As it rises, the water cools, condenses, and turns into
__________________. When the clouds hold enough waer, it will probably __________ or ________________.

You have drawn what is called a WATER CYCLE, and it's the way water gets around on our earth. All water, from the big ocean, to clouds, to rain and snow, to creeks, streams and rivers, and underground water (the water that we get from wells) is connected by the water cycle. The ocean is really a big reservoir for this water cycle, because about 98 percent of all the water on the earth is in the oceans! The rest is fresh water, in streams and rivers, or locked up in polar ice caps and glaciers.

But there's a little more to this water cycle. All plants give off water as a gas (called transpiration). This is another way that water finds its way back into the sky to make clouds.

And, most kinds of soil and rock can hold some water. We call this ground water, and it's the water we tap into when we drill a well. This water eventually ends up in streams and rivers, and on its way to the ocean. Make two more arrows on your water cycle diagram to show how transpiration and ground water fit into the water cycle.

Don't forget to color the thing that powers the water cycle on your diagram. If you can't remember what that is, review your work above!

UNIT 2
FINDING YOUR ECOLOGICAL ADDRESS

Portions of this activity were adapted from:

The Stream Scene
Watersheds, Wildlife and People
by Patty (Farthing) Bowers et al
Oregon Department of Fish and Wildlife
1990

Ecological Address:
At Home in Your Watershed
National Science and Technology Week 1992-1993 Packet
National Science Foundation, Washington, D.C.

For more information, contact:
Washington Department of Fish and Wildlife
Outreach & Education
600 Capital Way N
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Key Concepts:

- All land on earth is part of a watershed.
- A watershed is a system that is made up of all the land area from which water, sediment and dissolved materials drain to a common watercourse or body of water.
- All people live in a watershed.
- Most activities that are done on the land have some effect on the watercourses that drain the watershed.

Teaching Information

In the activities that follow, an “ecological address” includes the name of the water-shed in which students live as well as each successively larger stream and watershed - up to and including the major river from which the largest watershed usually takes its name. This system also includes the large lakes or the ocean into which that river feeds. These are the systems subject to pollution from failing septic tanks, excess lawn fertilizers, carelessly disposed crankcase oil, and other wastes from human activities. These systems are also affected by silt resulting from disturbed soils in the watershed.

When people have a greater understanding of their environment, they gain awareness of how their personal actions, local laws and regulations, and everyday business practices affect the integrity and stability of their ecological address and their larger biological community.

Materials for each pair of students:

- Washington watershed maps provided
- state highway map or other map showing streams and rivers in your local area
- paper for drawing their own watershed "maps"
- colored pencils or markers (can be shared by groups of students)
- string or yarn (about one foot per student)
- Copied student readings, if used.

Procedure:

1. Use one or both student readings to prepare students for this activity, and complete the student activity.

2. Begin by asking students to share their home mailing or street addresses. Write a few of them on the chalkboard. Explain that these postal addresses have been devised by society-that they are "social" addresses. They are important because people need to be located within their community by family, friends, and services such as the mail, police, fire or ambulance.

3. Now tell students that they all have another kind of address, called an ECOLOGICAL ADDRESS. Invite students to discuss the meaning of the word "ecological", eliciting from them the understanding that it refers to the relationship between an organism and its environment. Just as a postal address tells people one way that they are connected to a community, the ecological address tells people how they are connected to the land on which they live. In this activity, the ecological address will be based on an ecological feature they have just started learning about-the watershed.

4. Have students discuss the term "watershed". Let students share their definitions from the student activity page. Try to develop a class definition, which should be approximate this: all the land area that drains into a particular body of water. Tell students that they will be locating their own ecological addresses by finding and learning about the watershed where they live.

5. To help students understand the concept of watershed, trace the outline of your hand, wrist and part of your arm on the chalkboard. Color in the space between your fingers and label your arm "Blue River". Tell the students that this outline is a model for a watershed area. Your fingers represent streams that feed into the larger river (your arm). The colored space between your fingers is land, where people live. Let students know that a watershed's name is usually taken from the stream or river that serves as the main collector of all the water in the watershed. Ask students what the watershed you just drew would be called (The Blue River Watershed). Write the name on the board.

6. Ask students how large they think watersheds can be, then how small they can be. They should recall some of this from their reading. Impress upon the students that large watersheds include many small watersheds.

7. Students are now ready to work with the Washington watershed map package. Divide the class into pairs of students and give each pair copies of the watershed maps: 1-Watershed Resource Inventory Areas (WRIA) in Washington State; 2-Lake Washington-Sammamish.

On map #1, have the students locate WRIA 8. The Lake Washington drainage basin (WRIA 8) is comprised of all the waters funneling into Lake Washington then flowing out through Lake Union and Salmon Bay into Puget Sound at Shilshole Bay.

8. On map #2, have students locate the Sammamish River and the Cedar River. The Government Locks and Lake Washington Ship Canal were constructed in 1916. Prior to this, the Black River provided outlet at the southern end of Lake Washington. The Cedar River discharged into the Black River immediately below the lake, which then flowed into the Duwamish River to Puget Sound. The ship canal was dredged to provide navigation from Lake Washington through Lake Union to Puget Sound. The height of the locks raised the water level in the ship canal to that of Lake Union and lowered the lake level by about ten feet. The Cedar River was diverted into Lake Washington which increased the lake inflow, improving both the circulation and flushing rate.

9. On map # 2 have students locate the Piper's Creek watershed by drawing a line around it with colored pencil or marker. Then have them locate Bear Creek watershed in the same way with another color. With a third color, have them draw a line around the entire Kelsey Creek watershed. Use a fourth color to outline Tibbetts Creek watershed. With a fifth color, have them draw a line around the May Creek watershed. With a final color, have them draw a line around Thornton Creek. Make sure all teams have correctly identified the watersheds before asking the following questions:

a. If you lived two miles north of Renton, in which watershed (or sheds) would you live? (You would actually live in the May Creek watershed, which is part of the larger South Lake Washington watershed.) Remind students that a large watershed is made up of many smaller watersheds, and that both May Creek or South Lake Washington would be correct answers to the question.

b. If you lived one mile east of Bitter Lake, in which Watershed would you live? (Thornton Creek or North Lake Washington)

c. If you visited the Mercer Slough, in which watershed would you be? (Kelsey Creek)

d. If you lived less than a mile due west of Issaquah, in which watershed (or sheds) would you live? (You would live in the Tibbetts Creek watershed, which is part of the Issaquah Creek watershed, which is part of the larger Lake Sammamish watershed.

10.Suggest that everyone lives in a watershed, and ask students to explain why this is true. (All land has waterways running through it that drain into larger waterways. For example, in most urban areas rainwater feeds into storm drains. The drains then feed into nearby streams or rivers.)

11.Using maps 3# and #4 or a state or local map that shows streams and rivers, have each student name the watershed in which he or she lives. Explain that this watershed is the student's ecological address, and that this address describes how he or she is connected to the land and water system that drains it. In urban areas that are hilly, a city map will be needed to determine the exact watershed in which a house might be found. Depending on the proximity of waterways, the watershed named should reflect that students' ecological addresses can have several components, from the smallest watershed they can observe to a larger watershed of which the smaller one is a part. Have some students share their ecological addresses while other students follow along on their own maps.

12.Have students make a "map" of their ecological address. The map need not be to scale, but it should represent the watershed(s) in which the students live. As an alternative or additional activity, have the entire class make a larger map of the watershed on large sheets of paper.

13.Have students brainstorm a list of what they think can happen to water as it moves through a watershed. Highlight the things that are caused by human activity. These might include actions such as discarding oil or other wastes into a stream, clearing land (removing vegetation), or washing cars with soaps that contain phosphates (non-biodegradable chemicals). Then have students determine how and where these chemicals would travel in their watershed. They can do this by tracing the path from the smallest tributary in the smallest watershed as it empties into larger and larger watershed areas. Have students repeat the activity, this time looking at non-human influences on watersheds, such as heavy rains, wind, and other natural phenomena.

14.Have students calculate how many miles of stream and river are in their watershed, using the "scale of miles" on the published map. Using string to follow a curving waterway on the map can make measurement easier and more accurate. This measurement will help make clear to students the amount of area impacted by human activities affecting the watershed system.

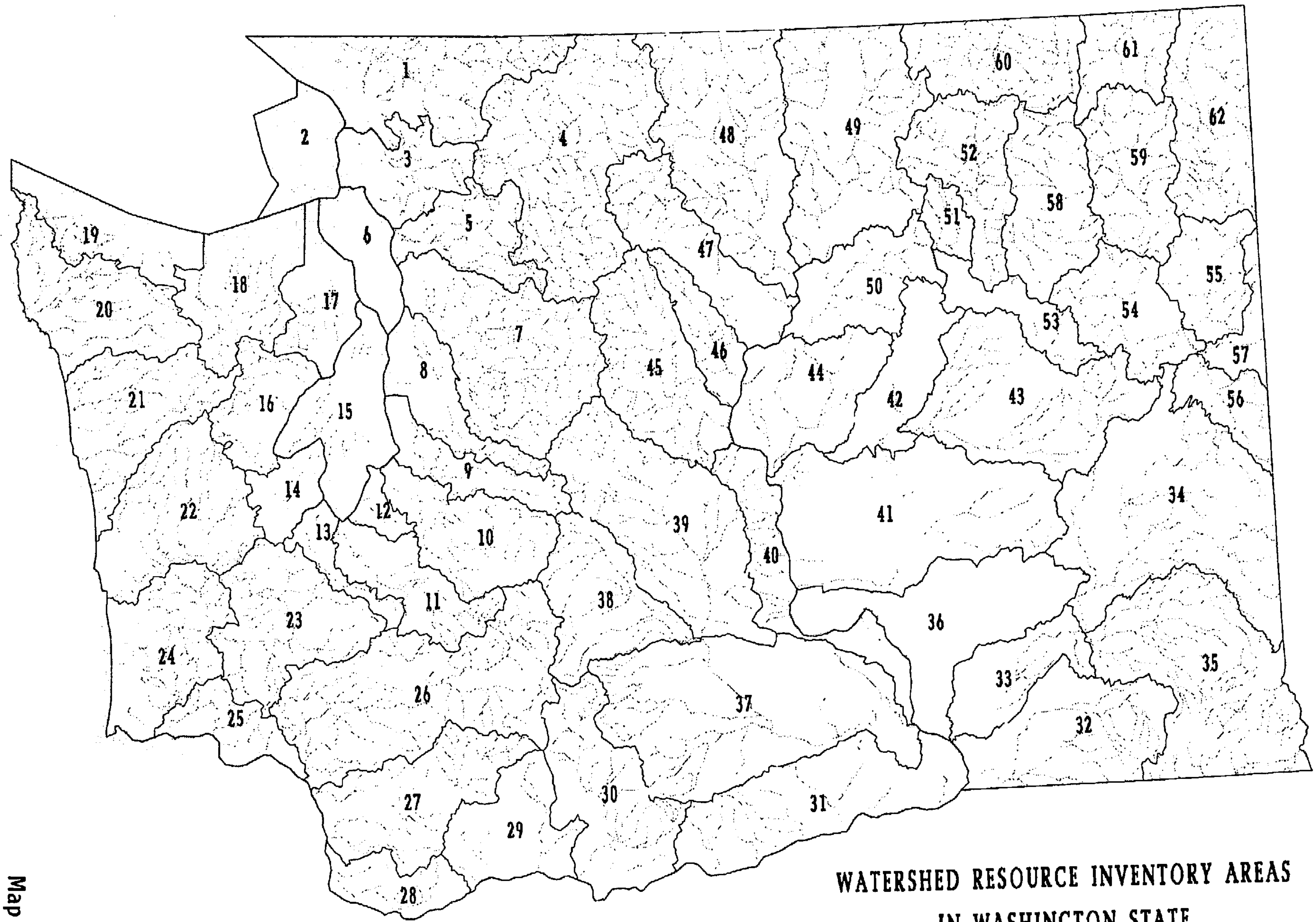
15.Using the state or local map, locate the fish hatchery you will be visiting. Identify its ecological address (watershed).

Extensions

- Build a list of who and what uses your watershed - from people to fish to wildlife. For each, make a list of the effects on the watershed.

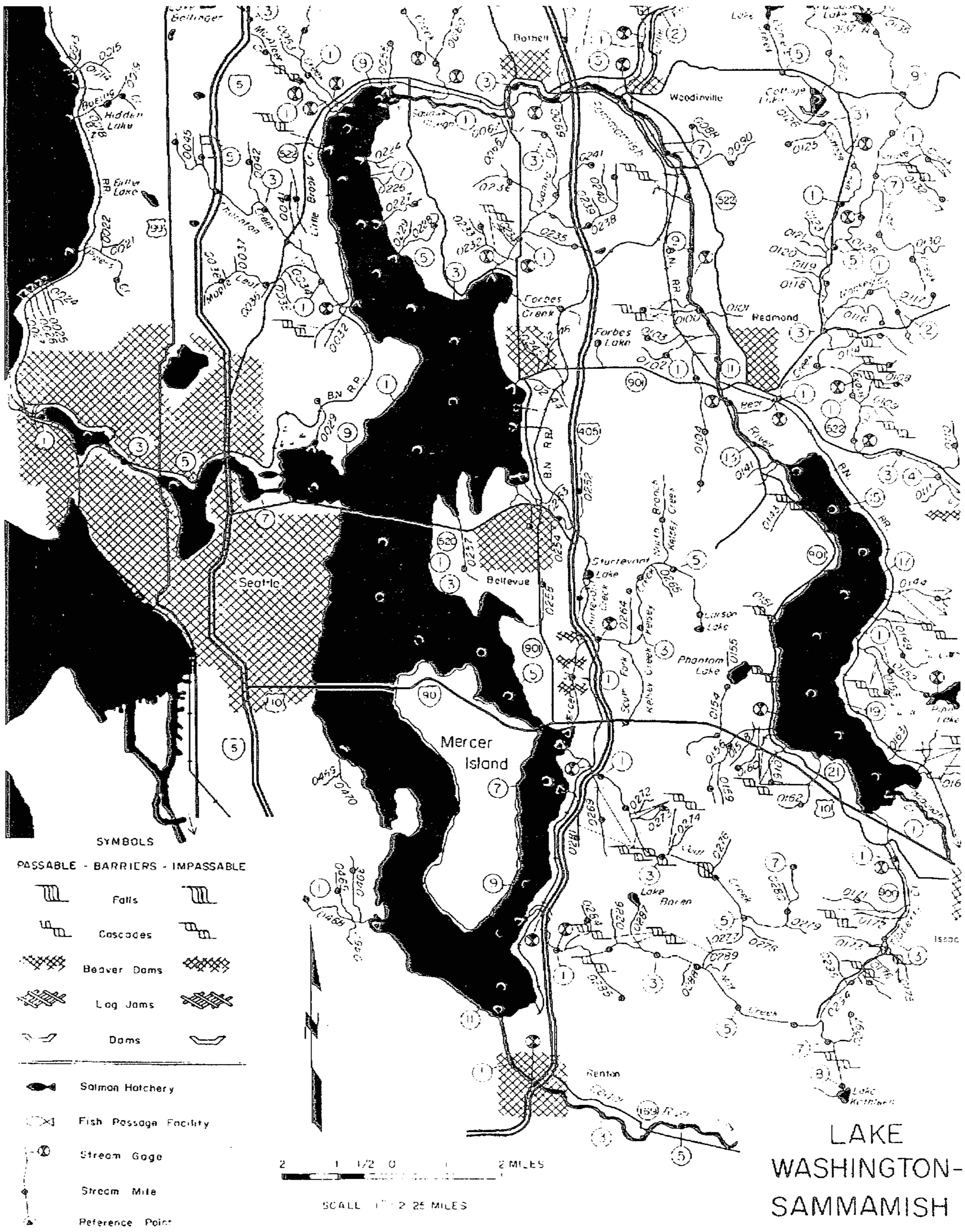
Key Words

ecological



WATERSHED RESOURCE INVENTORY AREAS
IN WASHINGTON STATE

Map #1


Bothell
Woodinville
Redmond
Forbes Creek
Forbes Lake
Hidden Lake
Cottage Lake
Seattle
Bellevue
Mercer Island
Sturtevant Lake
Larson Lake
Phantom Lake
Lake Boren
Renton
SYMBOLS
PASSABLE - BARRIERS - IMPASSABLE
Falls
Cascades
Beaver Dams
Log Jams
Dams
Salmon Hatchery
Fish Passage Facility
Stream Gage
Stream Mile
Reference Point
2 MILES
LAKE
WASHINGTON-
SAMMAMISH

Map #2

City of Seattle

Legend

Drainage Basin

Culvert

Open Stream Channel

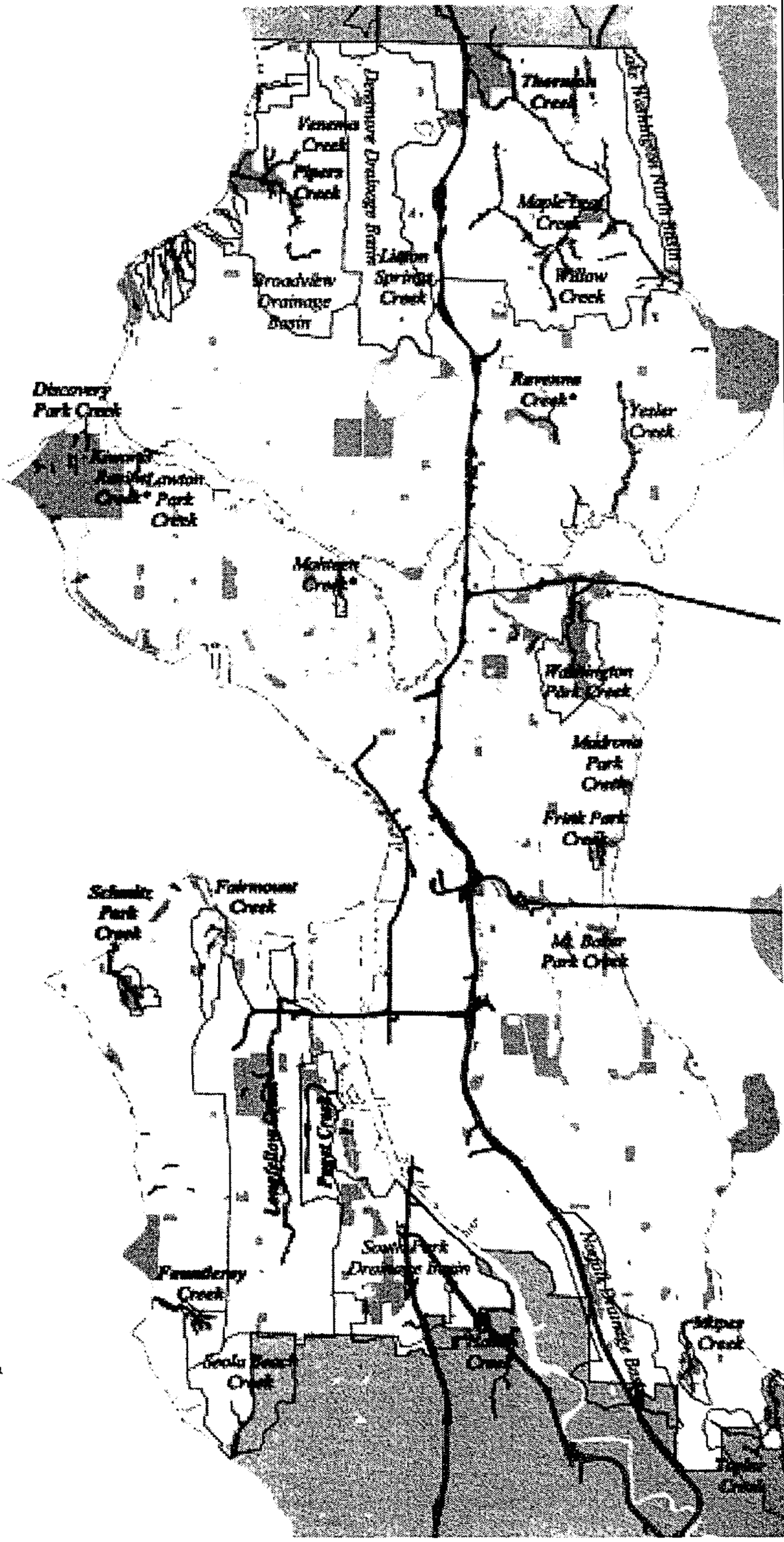
Highway

Parks

N
W E
S

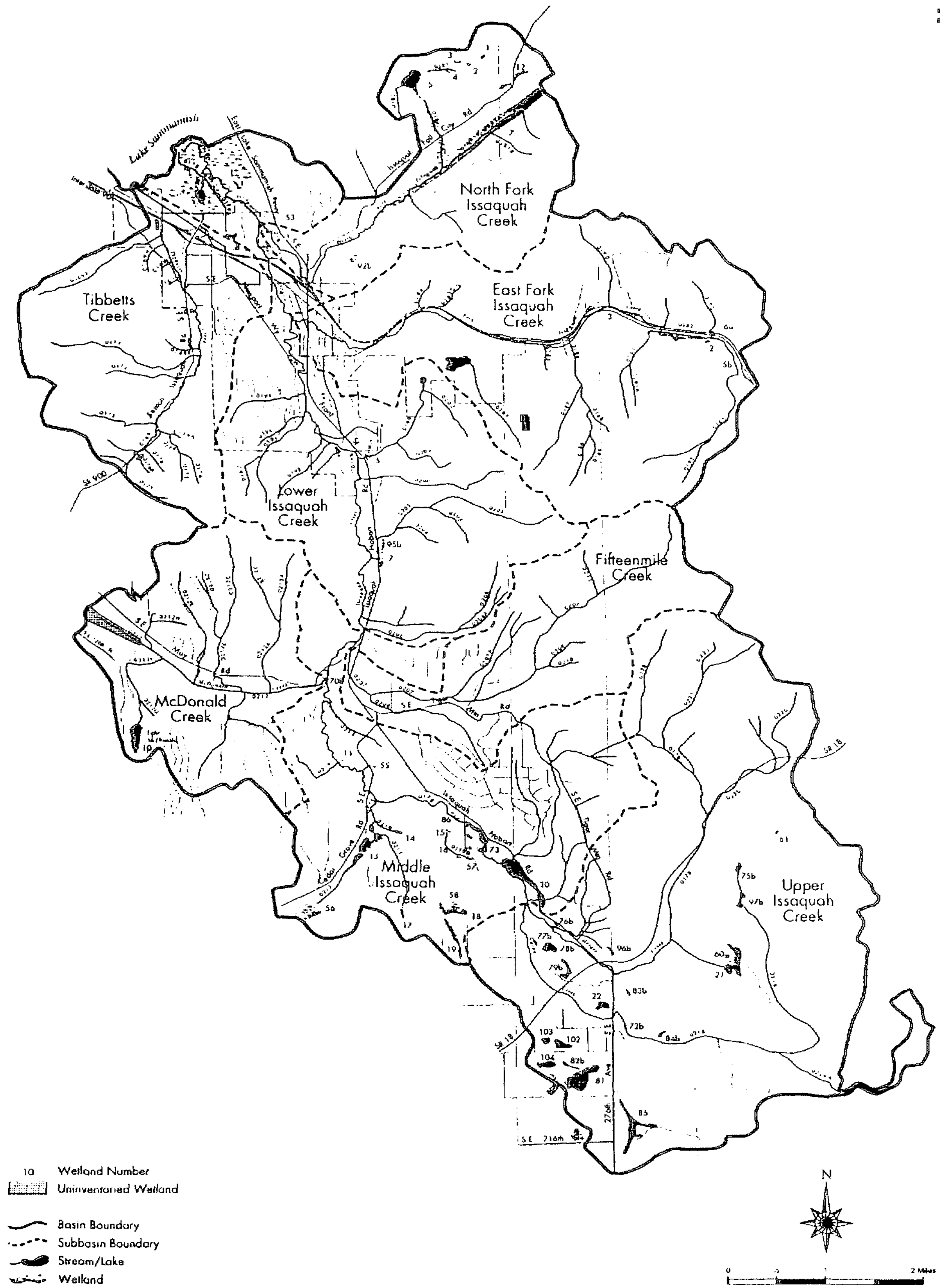
1 0 1 2 Miles

Produced by the City of Seattle



Map #3

Map #4


Lake Sammamish
North Fork Issaquah Creek
East Fork Issaquah Creek
Tibbetts Creek
Lower Issaquah Creek
Fifteenmile Creek
McDonald Creek
Middle Issaquah Creek
Upper Issaquah Creek
10 Wetland Number
Uninventoried Wetland
Basin Boundary
Subbasin Boundary
Stream/Lake
Wetland
N
2 Miles

Finding Your Ecological Address
Student Reading

Water runs downhill - we all know that. The instant that a drop of rain hits the earth, it begins its journey to the ocean (If it falls as snow, it has to wait until it melts!). Of course, not all water drops make it to the ocean. Some are taken up by the roots of plants and are transpired into the air through the plant's leaves. Some evaporate in puddles, or other areas that hold water. Some filter down into underground areas, moving slowly downhill. But most water drops end up as runoff, the water that finds its way into creeks, streams and rivers.

This long or short journey to the ocean takes place within a watershed. If you were to stand in a stream bed and look upstream at all the land the stream drains, you would be looking at the stream's watershed. Almost all the area of a watershed is land - not water! And almost everything that effects the stream that drains it happens on that land. In other words, ALL land on earth is in a watershed.

Watersheds can be big or small. A mud puddle has a watershed of only a few square feet. The Columbia River in the Western United States has a watershed that is 258,000 square miles. The biggest watershed in the country is the Mississippi River, which drains all the land between the Rocky Mountains and Appalachian Mountains!

Watersheds are separated by ridges, called divides. The Continental Divide of the U.S., for example, is in the Rocky Mountains. All the rain and snow falling on the west side of the divide flows into the Pacific Ocean. All the rain and snow falling on the east side of the divide, sooner or later, ends up in the Atlantic Ocean.

Now, Write Your Own Definition of a Watershed

Finding Your Ecological Address
Student Reading

Since all land is part of a watershed, it follows that all the factors that affect the land also affect the watershed.

The boundary between two watersheds is called a divide. A watershed is drained by a network of channels that increase in size as the amount of water and sediment they must carry increases.

Streams are dynamic systems with channels that collect and convey surface runoff generated by rainfall, snowmelt or ground-water discharge. The shape and pattern of a stream is a result of the land it is cutting into and the sediment it carries. The stream is forever evolving, always in the process of change.

The climate of an area obviously plays a big part in the processes within the watershed. Land and water are linked directly by the water cycle, usually in the form of rain or snow. Runoff, the gravity-powered journey of water downstream, erodes the rocks and soil of the watershed. At least some of the water percolates into the soil as groundwater. Except for high rainfall events, most of the water running in streams is from groundwater. Humans remove both groundwater and water in streams from the watershed for their own uses. Some of that water is returned to the watershed, sometimes not as clean as it was when removed.

The shape and slope of a watershed affect the speed of runoff, erosion and the amount of water that can percolate into the soil. The steeper the slope, the greater the possibility for rapid runoff and erosion. The makeup of the soil and rocks within the watershed (some being easier to erode than others) is another factor affecting the rate of erosion and deposition.

Plant cover benefits a watershed. Grasses, forbs, shrubs and trees intercept rain and reduce the force with which it strikes the ground. The plant canopy reduces the effects of wind, and slows runoff and erosion. Plant material also falls into the stream, delivering a vital food and energy source to the creatures of the stream. Plant roots bind together the soil, and reduce erosion by stabilizing stream banks and slopes.

Human activities continue to both help and hurt watersheds. Management of watersheds is essential to their good heath, both from a water quality and watershed quality point of view. Activities such as agriculture, recreation, timber harvest, livestock grazing, urban and industrial development, and mining can be harmful if they are not done carefully. Management of watersheds and their river basins is part of being careful with watersheds, and includes such activities as land use planning, zoning, permitted and prohibited land uses or types of development, restrictions on water use and water developments, pollution control, and citizen involvement in repairing watersheds and management decisions. We call this stewardship, and we are all responsible for it.

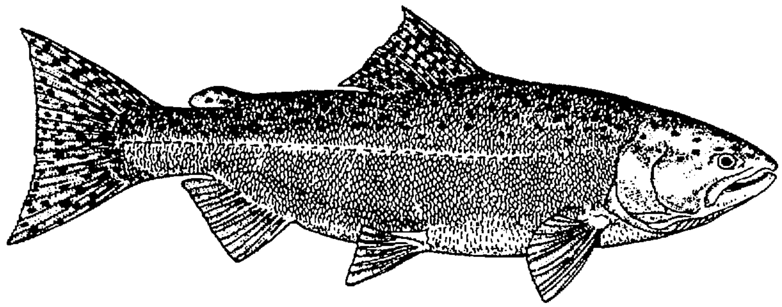
Stewardship is alive and well in Washington! People from all walks of life are coming forward to volunteer to help restore damaged watersheds, "adopt" portions of streams and rivers, assist the Department of Fish and Wildlife and other agencies in monitoring fish populations, and teach young people to be responsible anglers. There is much work to be done, but with help from people, watersheds and public attitudes towards them can be improved.

Rivers, hillsides, mountain tops, bottom lands, and even groundwater are all part of one system. They are linked together directly by the water cycle and watershed. The combination of climatic conditions, soil types, topography, plant cover, and drainage systems define the character of each watershed. We all live some-where within a unique watershed. We could say that each of us has an "ecological address", one that tells us where we live in relation to the watershed above and below us, and defined by the plants and animals that live there with us.

UNIT 2

TYEE'S MAGNIFICENT JOURNEY

This activity was adapted from:
The Magnificent Journey
Backgrounder, Bonneville Power Administration
1986, 1993



Key Concepts:

- Water travels through an earth system.
- Salmon have a complex and far-reaching life cycle that takes them thousands of miles, from fresh water to the oceans and back again.
- Salmon are faced with many hazards to their survival during their life cycle.
- Out of thousands of eggs that are laid in redds, a very small number of salmon complete their life cycle.
- People have caused problems for salmon, but they are working to solve many of those problems.

Teaching Information

Many fish live part of their lives in one habitat and then migrate to another. Some make their migratory journeys to mature and reproduce. Pacific salmon are an example of one of the most spectacular of the migrating species.

Pacific salmon are destined to spawn only once in their lifetime. Within their genetic fiber is an encoded instinct that drives them from the time of hatching along a monumental journey from their freshwater spawning beds downstream into the sea. Once in the sea they spend several years reaching the maturity needed for their single return journey to their original hatching ground, or "home stream".

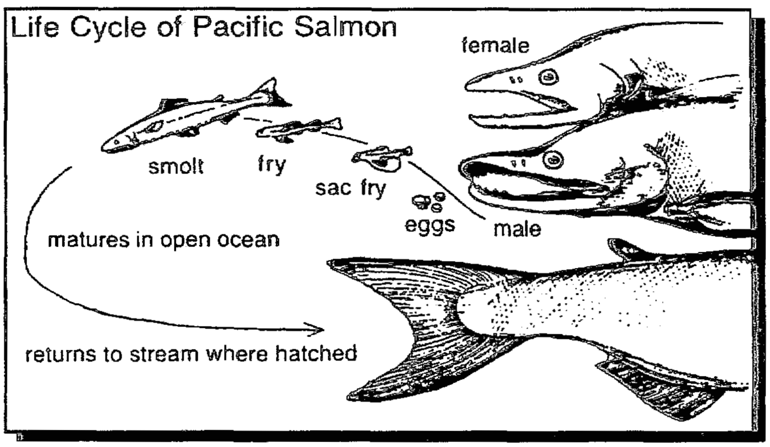
Salmon must face a myriad of hazards that serve as limiting factors in the completion of their life cycle. Limiting factors are those that reduce populations of living organisms. Sometimes the limiting factors are natural, other times they result from human intervention with natural systems.

The female Pacific salmon deposits 3,000 to 5,000 eggs in her freshwater nest. The eggs are deposited in a shallow gravel depression scooped out by the female. Once deposited, the eggs are fertilized by the male and then the female nudges the gravel back over the eggs to protect them. Within a few days both the male and female salmon have completed their reproduction and soon die.

The eggs, before and after hatching, are susceptible to many limiting factors. Smothering silt can be washed in suddenly from watersheds damaged by a variety of poor land use practices and/or events. These include erosion following road building, logging, and fires. Predators can eat some of the eggs and damage hatching populations. Dropping water levels can isolate salmon offspring in streamside depressions where they may die as the water warms and the oxygen in the water is used up. After hatching, the small fish - called "sac fry" - spend their first two weeks hiding in the gravel. Gradually, they absorb their yolk sac and become known as "fry". The fry emerge from the gravel and begin foraging for food. In a few weeks, if they survive, they begin their journey. Some head directly for the ocean.

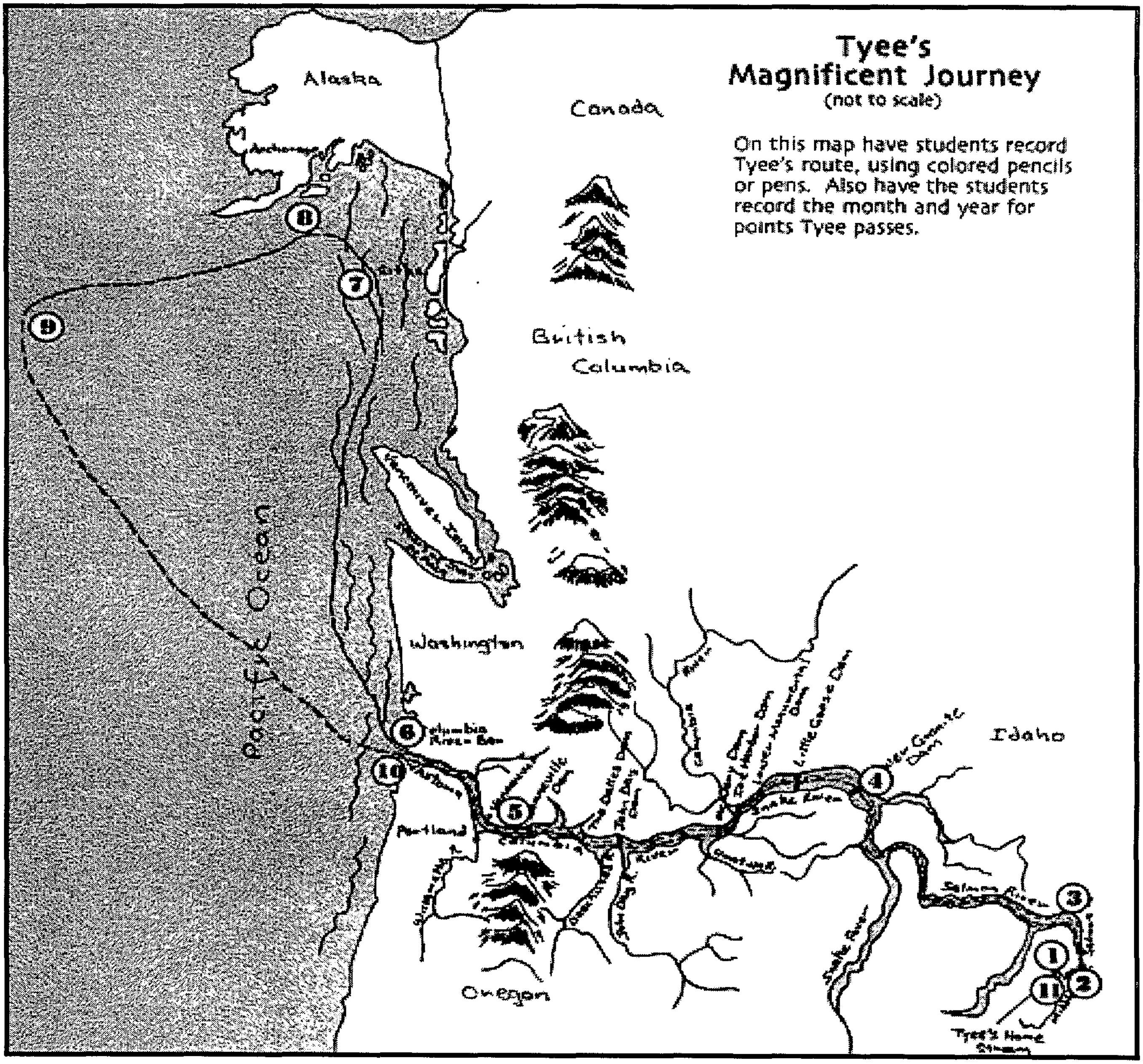
Depending on the species, young salmon may spend several months to as much as a year or more in a river before migrating to the estuary and then to the ocean.

The small, ocean-bound salmon, now called "smolts", are at once confronted by hazards on their downstream journey. Examples include dams, low water in streams, predatory birds, mammals and fish, and anglers that catch them thinking they are trout. Up to 90% of the salmon that hatch never reach the sea.



In the ocean, salmon grow rapidly by feeding on the ocean's rich food supply. Predators such as sharks, killer whales, and other marine mammals take their toll. Humans also fish for salmon commercially and for sport.

In two to five years, Pacific salmon start the journey that will guide them back to the rivers and streams leading to their own hatching site. The upstream migration from the ocean is also a series of hazards. Dams hinder their journey and would block it completely if fish ladders were not installed. Grand Coulee Dam, on the Columbia River, had no such ladders, and blocked over 500 miles of river (excluding the tributaries) to salmon. Humans, bears, eagles,



1 September 1993 (in the redd)

2 March 1994 (emerges)

3 October 1994

4 April 1995

5 May 1995

6 June1995

7 August 1996

8 October 1996

9 July 1997

10 March 1998

11 September 1998

and other mammals also take some of the salmon along the way. Landslides and log jams provide unexpected new barriers. Natural waterfalls and rapids challenge salmon to get over them.

Once back on the spawning grounds, the life cycle of the Pacific salmon can begin anew.

This activity can be approached in a number of ways. You can:

- have students read the entire story as background for the next activity, "Hooks and Ladders".
- have students read only part of the story (perhaps through the part where Tyee enters the Columbia on her return journey), complete the activity "Hooks and Ladders", then have THEM write the remainder of the story.
- read the story to the students, pausing to discuss each "stage" in the salmon life cycle. One way to approach this is to list all the things salmon need to complete that stage, such as "the downstream migration".
- have students record Tyee's journey on the map provided (map is NOT to scale!). They can do this as they read, or return to the story after they read it to get the needed information. The story notes the months and years Tyee passes points identified on the map. Have students use colored pens or pencils to trace where Tyee goes, one color for her downstream and ocean journey, and another for her return trip (change colors when she begins her journey back to the Columbia River). Also have them note the month and year these points are passed, such as "in redd-September 1998" and "enters ocean-June 2000", using the same color as the journey trace. Use any year to start you want. If she is conceived in September of 1998, she:
    - should be passing Lower Granite Dam in April, 2000
    - should enter the ocean in June of 2000
    - should pass Sitka, Alaska in August of 2001
    - should pass Anchorage, Alaska in October of 2001
    - should begin the return trip to the Columbia River in July of 2002
    - should enter the Columbia River in March of 2003
    - should be back in her home stream to spawn in Septemberof 2003.

You could also use a map drawn to scale to trace Tyee's route; this allows you to calculate the number of miles traveled between each point. A large classroom map can also be used with colored yarn to trace Tyee's route.

Materials

Copies of the reading (If you elect to have the students complete the story of Tyee the Lucky, copy only the part you want them to read.).

Extensions

1. "Hooks and Ladders" (p. 143), can be used as an extension to this activity.
2. Build a class, group, or individual salmon life cycle mural based on the story.
3. "Columbia River Salmon: Legends and Stories of the 23rd Century (p. 215)" is a natural extension of this activity.

Key Words:

sac fry; algae; bar; commercial fishing; Endangered Species Act; estuary; fertilize; fingerling; fishing regulations; fry; gene; gills; gillnet; habitat; imprinting; larvae; midge; migration; navigate; oxygen; pesticide; predator; riffle; run; silt; slime layer; smolt; spawn; sperm or milt; sport fishing; storm drain; yolk sac; zooplankton

Tyee's Magnificent Journey
Student Reading

A miracle. That's what Native Americans called the vast runs of salmon that returned each year from the ocean. Returning to the streams where their lives began from a huge ocean, these fish were magical and great spirits. Even today, the life cycle of a salmon still seems a miracle. This is because the long journey that salmon make from the gravel in a stream to the ocean and back again to spawn is more dangerous than ever.

Salmon lay between 3,000 and 5,000 eggs in a nest in the stream gravel. But did you know that only two fish return from all those eggs, on average? If the water level in a stream drops too low, thousands of eggs can be wiped out. Bigger fish, bears, seals, and sea lions all take their share of salmon. Nature has provided for this loss by enabling salmon to lay these thousands of eggs.

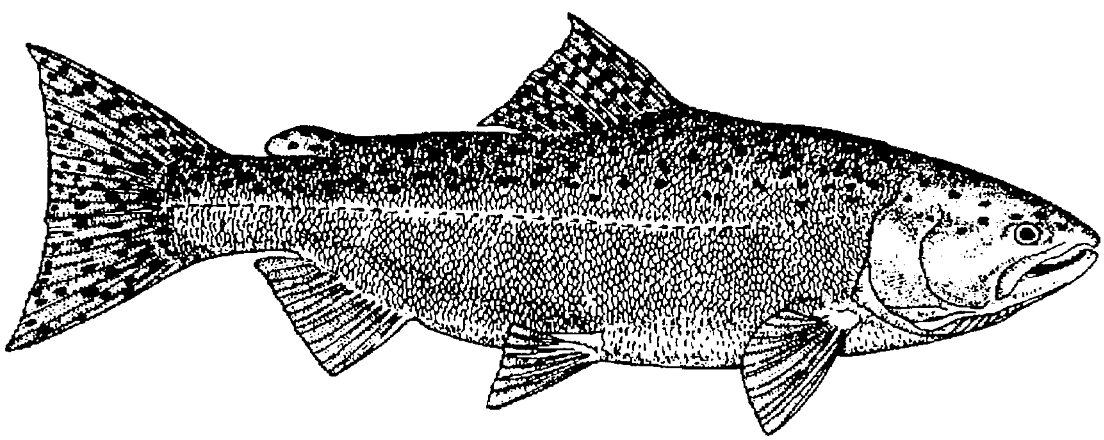
But Nature alone cannot make up for what people have done to the salmon. Dams blocked large areas of the wild salmon's spawning areas. Roads and towns developed around salmon streams. Logging and farming practices fouled rivers with sediment. So did pollution from cities, factories, and houses. Catching salmon became too easy.

Salmon runs became smaller and smaller. Today, some types of salmon are in danger of disappearing forever. The home of the Pacific salmon, the Eastern Pacific Ocean and the great river systems that pour westward into it, don't seem to be the kind of homes they once were for Pacific salmon.

Humans were at first slow to see what was happening to the salmon of the Pacific Northwest. Good places for salmon to mate, lay eggs, and produce more salmon were being lost. The long journey from the spawning areas to the ocean and back again was being delayed or blocked. People continued to catch salmon at high rates.

Then people began to recognize that something had to be done to help salmon. A law called the Endangered Species Act came into play, helping people to see that many kinds of salmon were in danger of being lost forever. Today, many people are busy trying to help salmon survive. Fishers, landowners, and government are all part of this work.

To understand what needs to be done to help salmon, people need to know a little bit about the life of a salmon. This story, about just one female Chinook salmon, "Tyee the Lucky" will help you understand.



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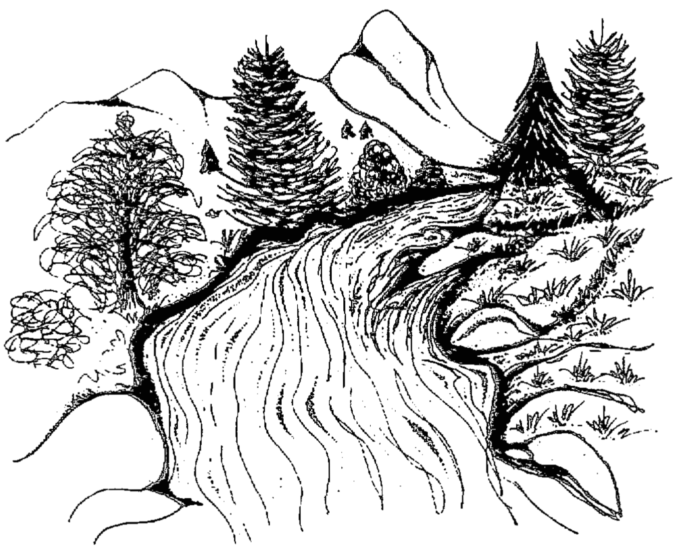
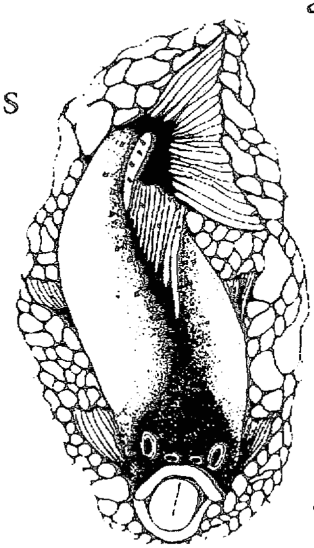
The Cycle Begins

High in the mountains of central Idaho, a creek too small to have a name runs cold and clear. Thousands of years in



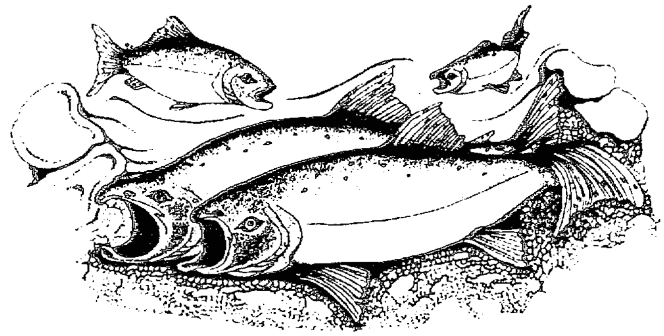
the past, great melting ice sheets left a U-shaped valley with a gravel floor. The gravel can still be seen on the creek bottom.

It is September. Leaves are yellow and brown, and frost covers everything along the stream bank. The first snowfall is not far away. A reddish-brown female chinook salmon lays just



under *riffles* of rushing water. She is battered and exhausted. She seems to be resting, perhaps waiting for something.

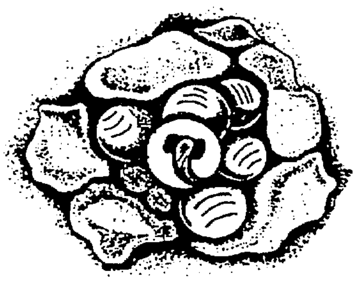
Another salmon appears. He is darker, with cream-colored splotches on his body. He moves next to her, facing upstream as she is. These



salmon are mating, or *spawning*.

They are Chinook salmon, also called "tyee" or "king" salmon. They are the largest and live the longest of any Pacific Northwest salmon.

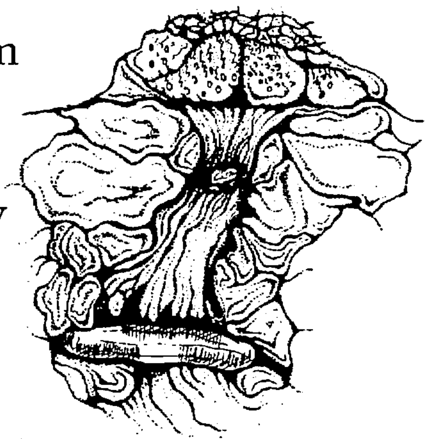
The female lays about 5,000 bright pink eggs in a depression in the gravel (called a redd) which she has dug with her tail. Then the male moves in to fertilize the eggs. Finally, the female moves just upstream. With her tail, she kicks up pebbles that drift down over the eggs, hiding and protecting them.



Now the eggs are protected from sunlight, strong currents and hungry animals. For the next four weeks or so, the eggs remain hidden in the gravel. If the redd is not disturbed the eggs will remain safe.

In a few weeks, the eggs begin tochange. Inside each living egg, a head, eyes, and a body begin to take shape. Somewhere among this closely-packed redd lies Tyee the Lucky. Salmon don't usually have personal names, but this female is special. Read on to find out why she is called "lucky".

Tyee is lucky that the water rushing through the gravel in the redd is only about 55 degrees Fahrenheit - perfect for a salmon. Warmer water could end her life early. She's lucky, too, that there have been no sudden torrents of water. Heavy rainfall could increase the current in the stream, removing her gravel protection.



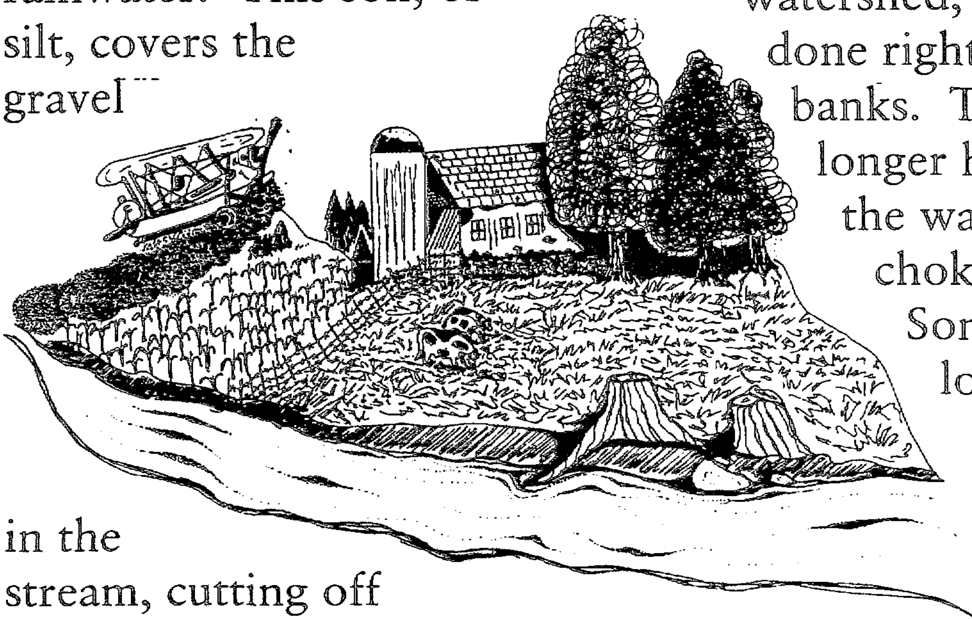
Upstream from Tyee's redd, many riffles of water running over rocks mixes air into the water, giving it a rich oxygen supply. Without oxygen, the eggs would die.

Ducks and other birds, raccoons, and larger trout love to eat salmon eggs. But Tyee is hidden and protected in the stream gravel. Tyee the Lucky.

Tyee's stream is a healthy

one. It had been spared from heavy logging years ago because it was hard to get to. Then, not long ago, the stream and its banks were protected by laws passed to save salmon habitat. Before that, streams all around it had not been so lucky.

In one creek about the same size, a mining dredge once ripped up the streambed. Even though that was years ago, loose soil from the mining is still carried downstream by rainwater. This soil, or silt, covers the gravel



in the stream, cutting off the stream's oxygen-carrying water to the eggs. The eggs suffocate.

On another stream, grazing cattle had trampled the stream bank, releasing silt. Pesticides used on farm crops upstream had poisoned the eggs and fish during some years.

Now, people were busy trying to bring this stream back to health. Cattle were fenced out of the stream, and farmers using pesticides were being more careful, or not using them at all. This stream was "on the mend".

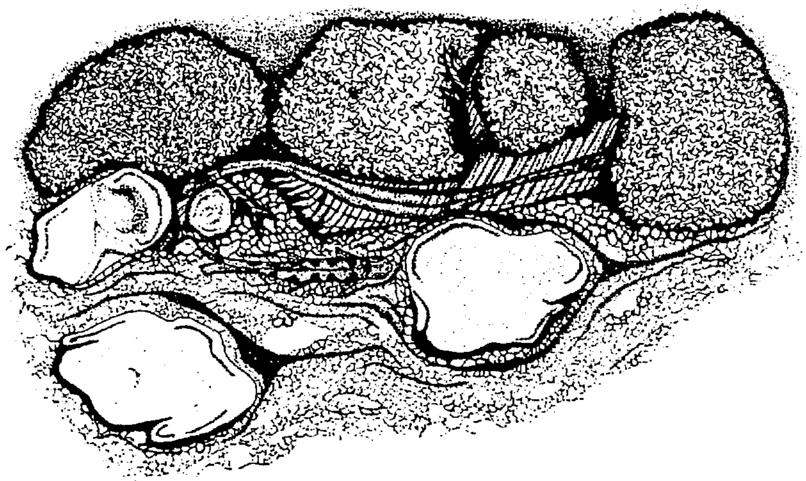
In other streams in the watershed, logging had been done right to the stream banks. These streams no longer had shade to cool the water. Many were choked with debris. Some streams had lots of silt from logging and road building.

But at some places in the watershed, people were working to repair this damage. It would take time to repair all of it. The job seemed almost impossible. But the work was starting. Laws were being passed to make sure people protected streams, no matter what kind of work they were doing. People were working together to protect Tyee and her kind. It would take more - much more - of this kind of time, work, and money to make a difference.

Tyee didn't know about all this damage or work to repair it. She was still an egg. Her stream was healthy.

FROM EGG TO FRY

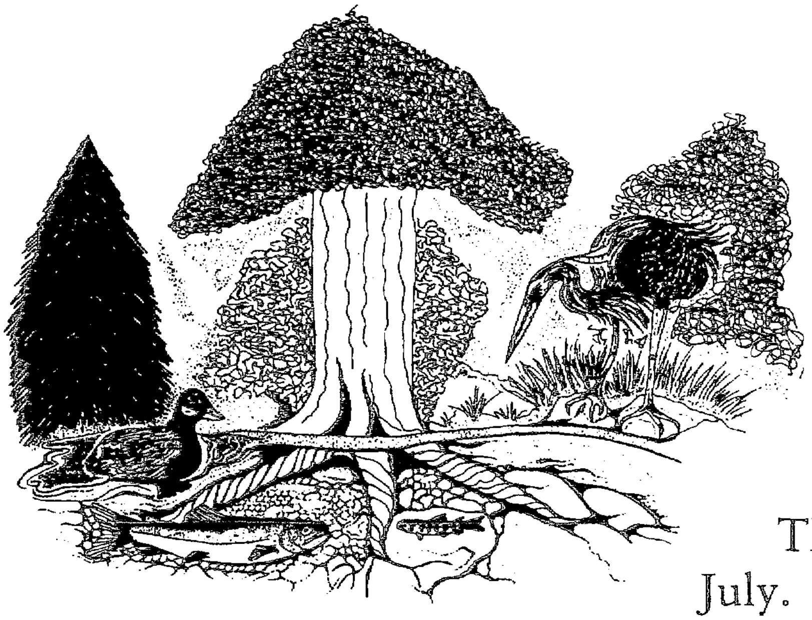
It is winter at Tyee's redd. Snow covers the ground. All is white but the stream itself. Thin ice sheets cling to the banks of the stream. Little can be heard except the soft gurgle of the stream. Nothing seems to be alive. But in the gravel, things are happening.



By Valentine's Day, the eggs remaining alive have hatched. The hatchlings stay under the gravel. Tyee has transformed herself into a small creature called an sac fry (alevin). Her eyes are huge compared to the rest of her body.

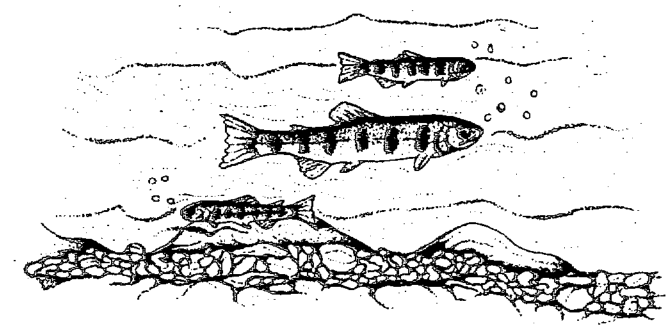
An orange sack, called a yolk sac, hangs from her body. The yolk sac contains all the proteins, sugars, vitamins, and minerals she needs to grow. As she grows, the sac gets smaller.

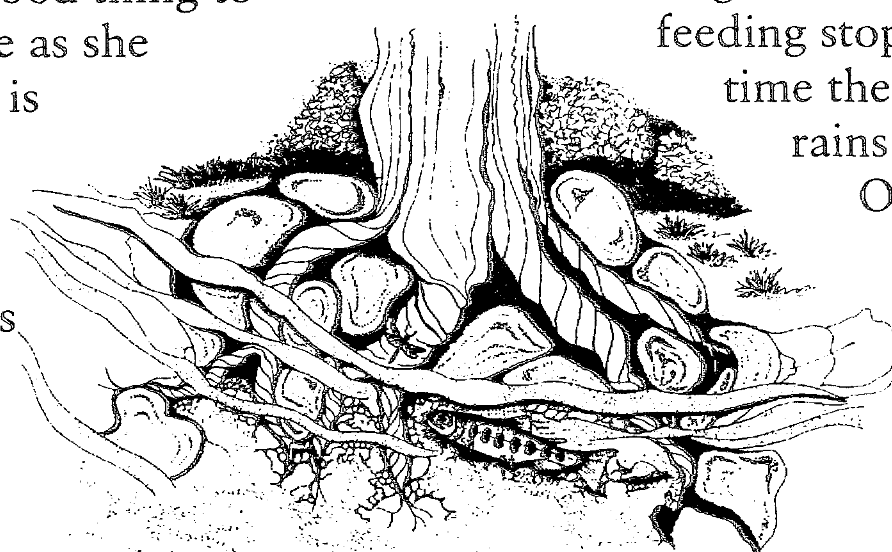
One night in March, Tyee gets an urge to slip upward through the gravel. She emerges into the stream as a tiny fish, called a fry. Her eyes are still bugged out, and she is about the size of a fir needle. She stays away from the direct sunlight, in shallow pools near the edge of the creek where the current is not strong. Tyee darts around feeding on tiny creatures. She is quicker than most - a good thing to be because as she feeds, she is easy food for trout and other fish, ducks and herons. Tyee the lucky.



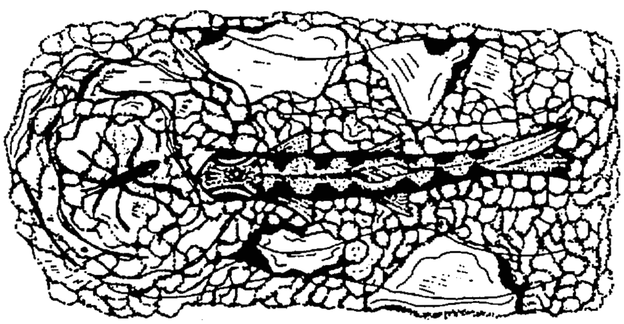
Some fry start their *migration* to the ocean as early as May or June. But not Tyee. She will be in fresh water for a full year before she has her first taste of salt water.

The creek gets shallow in July. Tyee lets the current take her downstream. She is in no hurry, and stops along the way under root wads, fallen trees, and boulders. These places make good resting and feeding stops. By the time the first Fall rains come in October, she is in the Middle Fork of the Salmon River.





By September, Tyee has grown to a ***fingerling.*** She is well over three inches long. Scales protect the length of her body. Over the scales, a ***slime layer*** of mucus has formed to protect her from disease and help her slide through the water. She has developed faint oblong marks along her silver-colored sides to help hide her from ***predators.***



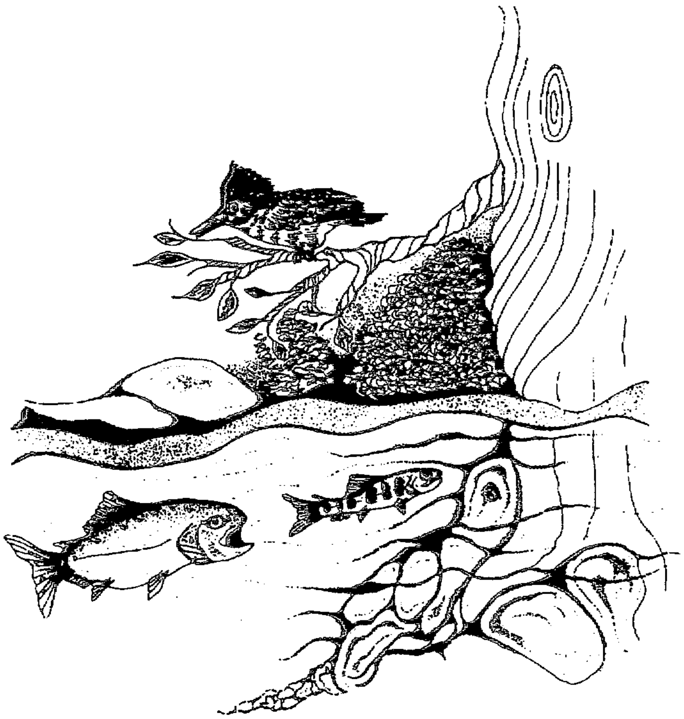
Tyee is big enough now to be a real hunter. She snaps up mosquitoes and other insects that come near the water surface. She nabs an ant unlucky enough to have fallen into the water.

Her mouth helps her eat and breathe. She takes in water through the mouth and forces it out through the gills on each side of her head. The feathery gills contain blood vessels which - just like your lungs in air - take up oxygen from the water.

Tyee doesn't have ears, but she can hear well. Low frequency sounds vibrate through the water to a row of small holes along each side of her body. These holes open to nerves that let her "hear" danger coming. Salmon also have nostrils and a good sense of smell. They can smell predators and food.

Tyee can smell home too. As she travels farther from where she emerged from the gravel, she is also learning to get back, years later. Salmon can return to the stream of their birth using this learning. Humans call this homing, but they don't yet understand how it works. Somehow, the smell, taste, or some other thing about the water in Tyee's stream become lodged in her memory.

So far, life for Tyee has been mostly good. But she has been



chased by more than one large fish. In August, a kingfisher perched on a branch above her took aim and headed straight for her. Thanks to her large eyes and quick reactions, she darted away before he got to her. Not every young salmon is so lucky.

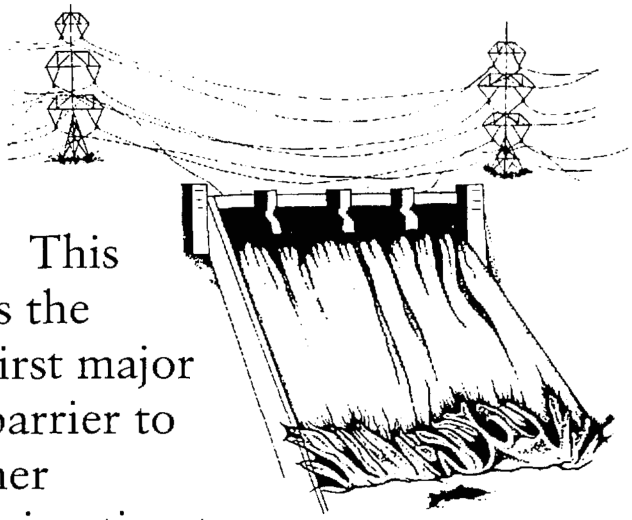
In fact, only about 15 percent of the eggs in her redd made it through the fry stage. And conditions for her brothers and sisters were better that average. By the end of summer, only 750 salmon of the 5,000 eggs were still alive and feeding!

The Downstream Journey

As Tyee begins the winter of her first year, her growth slows. There is not as much food, and she doesn't seem to be as hungry. As the snow falls, she waits for another spring. In April, it finally comes. Snows begin to melt and spring rains begin. The water level rises and the runoff sweeps young salmon downstream.

Tyee lets the water do the work. She travels with her head upstream as the water carries her toward the unknown. Traveling at night to avoid predators, she feeds on midges, worms and snails. She is changing both inside and out, preparing for her life in salt water. With these changes, she becomes a smolt.

She enters the Salmon River, then the Snake, a larger river that forms the border between Idaho and Oregon. Other smolts from other streams join her in a mass migration to the sea. The Snake River rushes her along, then suddenly the current is almost gone. It is April, and Tyee has entered the reservoir for Lower Granite Dam.

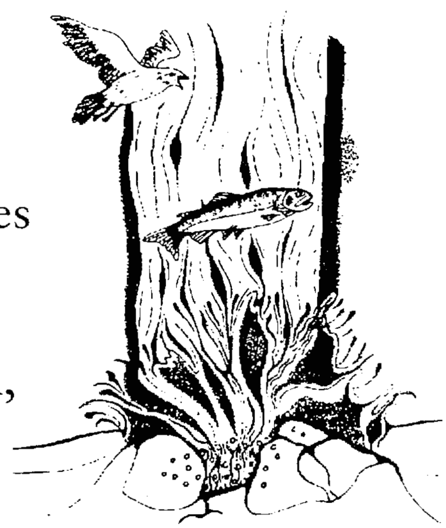


This is the first major barrier to her migration to the ocean. Before dams were built, the trip to the ocean from her home stream might have taken three or four weeks. But the dams had slowed the water, and now the journey took closer to two months.

Downstream, other dams await: Little Goose, Lower Monumental, and Ice Harbor on the Snake River. When the Snake joins the Columbia River, four more dams await: McNary, John Day, The Dalles, and Bonneville. All of these dams have been built in the last 60 years. The dams have been good - for people!

Dams make electricity by holding back the river water in large reservoirs, then letting it run through turbines. Falling water spins the turbines to make the electricity. This is a clean and cheap way to provide power for people. Dams also provide irrigation water for crops and help control flooding. The dams also have locks which allow barges to pass up and down the river, carrying goods and crops.

But from Tyee's standpoint, dams are not all that great. The reservoirs behind the dams have little current, and her trip to the ocean takes much longer. Squawfish, walleye, and bass



are waiting to make a lunch out of her all along the way. They all survive well in the slower water created by the dams.

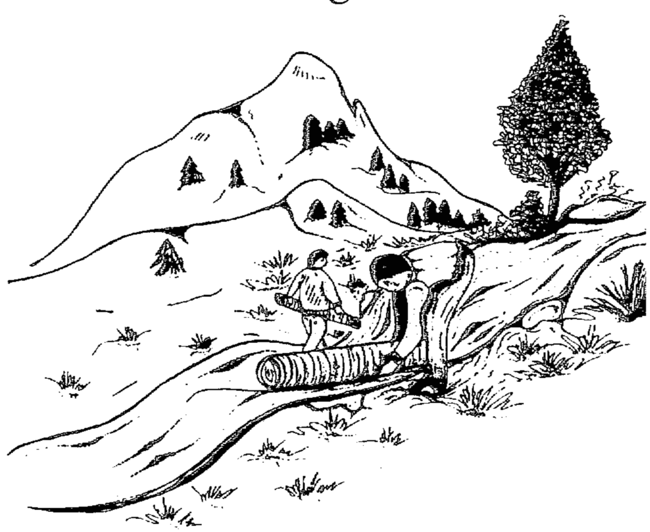
Just passing a dam is hard for Tyee and her kind. At lower Granite Dam, a fish screen catches her just in time and guides her away from the whirling blades of the turbines.

At another dam, the water is high and one spill-way is open. Tyee is stunned for a short time after a fifty-foot drop over the spillway. She regains her senses just in time to escape from a gull waiting for her above the churning water.

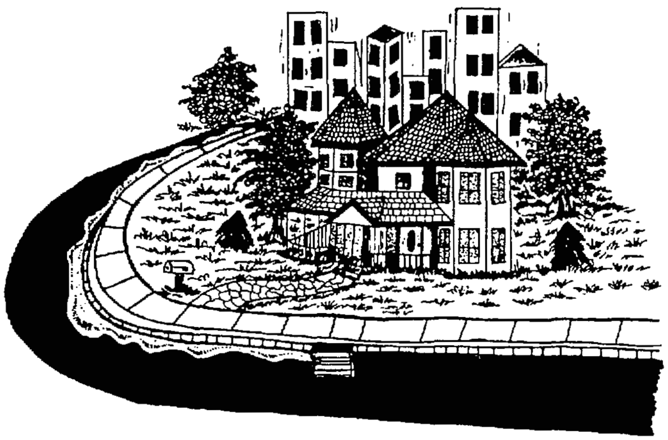
Tyee's luck holds as she travels down the Columbia, toward the ocean. Many of her kind were not so lucky. At each of the eight dams she has passed, ten to fifteen percent of the salmon smolts don't make it.

People are working to make the trip easier for salmon. Newer and better screens are being installed at the dams. Water releases at the dams are being timed to provide faster flows down the river when the smolts are traveling through. Some of the smolts are even collected at Lower Granite Dam, placed in a barge full of water, and given a free ride down the river. They are released below Bonneville Dam.

Work is going on at other places, too. In small streams where salmon spawn and hatch, people are leaving trees and shrubs along the banks to

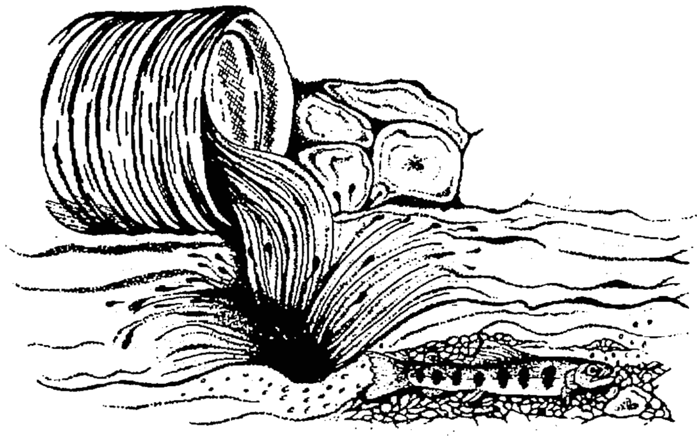


keep the water cool and provide food for the insects that live in the stream. They are placing logs and boulders in the stream to create places for fish to hide and grow. They are protecting the stream water from pollution. All this work costs money, but it is needed to help salmon and other fish. Almost everybody helps pay for the work, through electricity rates and taxes. Many people even volunteer their own time and money to do these jobs.

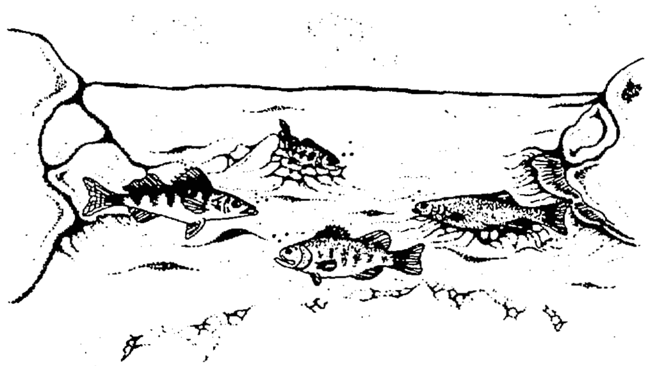


After passing Bonneville Dam in late May, Tyee finds herself once again in a flowing river. She passes between the cities of Portland and Vancouver. Here, the water tastes different.

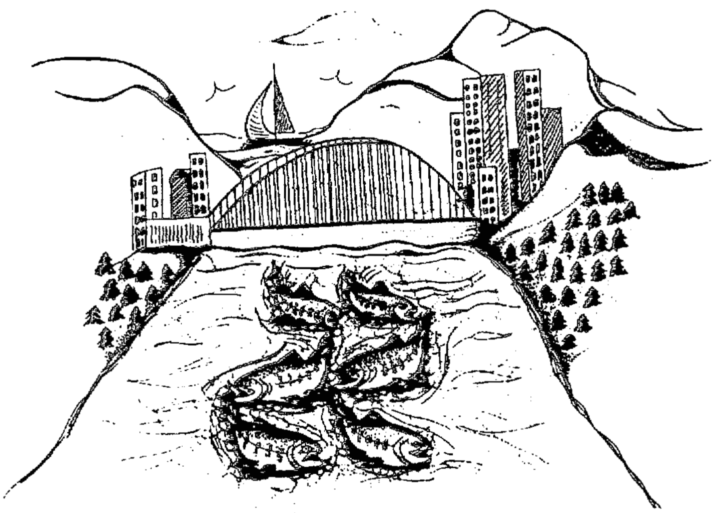
In cities, rainwater hits rooftops, paved streets and parking lots. Instead of soaking into the ground, water quickly runs off these surfaces and into the nearest ***storm drain.***



These drains lead directly into rivers and streams. Pollution is carried with the water. Such things as grit from rubber tires, detergent from washing cars, fertilizers from lawns and gardens, and even used anti-freeze and oil from cars is sometimes in the water. Tyee is glad to get past this part of her trip.



As Tyee travels past Portland



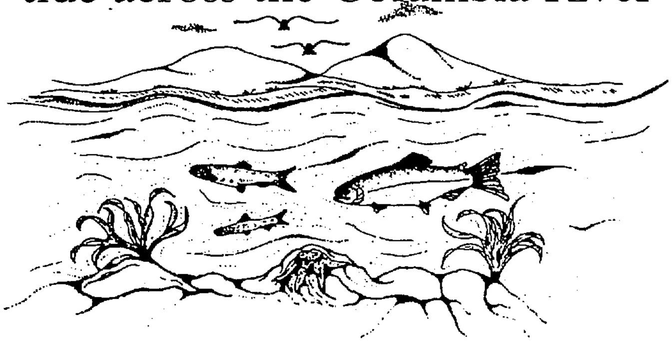
and Vancouver, more smolts from other rivers and streams join her in the journey to the sea. The river is full of life.

What's this!? Suddenly the current seems to be going the "wrong way". Again, the water tastes different. Tyee finds herself in the Columbia River *estuary*. Here, twice each day, the incoming tide pushes seawater back up the river. The estuary is rich in new kinds of food: *algae*, crab *larvae*, shrimp and small fishes.

Tyee stays in the estuary for about two weeks. She still has to be careful. She is only about six inches long, and has to stay out of the way of larger fish. Pelicans and other fish-eating birds live in the estuary also. In the slack water of the estuary, Tyee joins other smolts near the surface of the water. Here, they jump out of the water as high as they can, but not to catch food. People don't know why they do this. Perhaps it is to celebrate a lucky trip from their "home streams" to the sea. Tyee should celebrate. She is one of only 300 left of the 750 fry in her redd and the 5,000 eggs

laid by her mother. Tyee the Lucky.

One night, after a warm, clear day in June, Tyee has an urge to begin the next stage of her life. She rides the night tide across the Columbia River



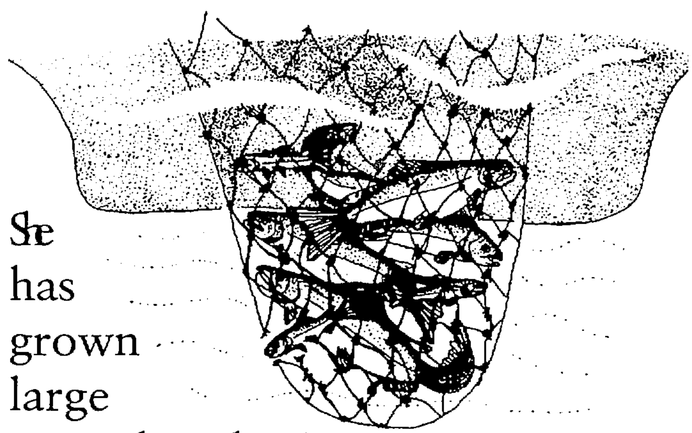
bar and swims into the great Pacific Ocean. She will not see this place again for three years.

In the sea, there is new food to catch. At first, Tyee's diet if mostly ***zooplankton*** - tiny animals in the ocean water. Later, she finds shrimp and other animals. Her body takes up the color of the shrimp, changing the color of her flesh from white to pink. Anchovies, herring and other fish are added to her diet.

Sea birds, tuna and larger salmon are everywhere, hungry to make a meal out of her. But she survives and grows. She heads northward, past the Strait of Juan de Fuca. She now weighs about a pound and a half.

Suddenly, she finds herself in a thick group of all sizes of fish. The group is being drawn together by a huge net. The bottom of a fishing boat can be seen above.

Tyee slithers among the trapped fish in the net. She just manages to slide through one of the openings in the net. She has been saved only by her small size. A new predator - people - will be after her now.



She has grown large enough to be valuable to both sport and ***commercial fishers***.

For as long as there have been people and fish, humans have taken fish for their own use. The earliest people in the Pacific Northwest used salmon for food and many other things. To them, the salmon was a spirit, a link between the natural world and the world of people. They were in balance with the salmon.

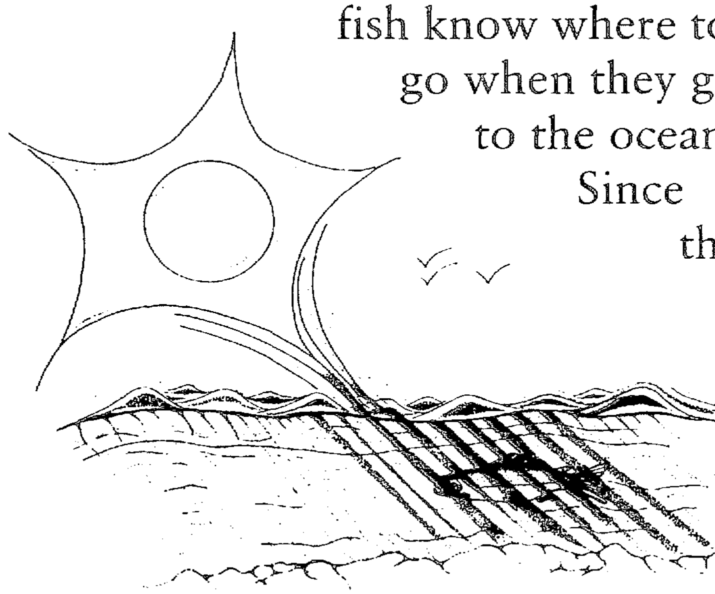
Today, many more people live in the Pacific Northwest. There has been rapid growth, and with it, the need to catch more salmon. People got better and better at catching salmon. At the same time, people damaged the places where salmon lay their eggs and are reared. Dams greatly reduced the number of salmon traveling both up and down the river. Soon, the supply of salmon was not enough.

People argued about the causes of poor salmon *runs*. They blamed each other. Today, all the people who value salmon are beginning to see that they have to work together to save the salmon. This is why so much work is going on to help these fish.

Tyee is helped also by *fishing regulations*. These laws set limits on how many fish can be caught, when they can be caught, where and who can catch them. But Tyee doesn't know about all this. She swims northward to the northern tip of Vancouver Island.

Tyee is now a clever hunter, eating whenever she can. She doubles her weight every three months in her first year in the ocean. By August of her second ocean year, she passes Sitka, Alaska, and weighs twelve pounds.

One of the great mysteries of the salmon is how these fish know where to go when they get to the ocean. Since they



haven't been in the ocean before, they couldn't have "remembered" what their route should be. By tagging fish and tracking them in the ocean, scientists have learned that chinook salmon stay fairly close to shore. But very little is known about how they ***navigate***. Tyee may use the angle of the sunlight in the water, water temperatures, the earth's magnetic field, or ocean currents to find her way. Or it could be that the information needed is ***imprinted*** in her ***genes***. She just knows without ever having to learn.

Coho, chum and sockeye salmon all have different ocean travel routes than chinook. Some stay inside the island groups off British Columbia in more protected waters. This is what Tyee does, swimming up to 15 miles each day. After two years in the Pacific - the third year of her life - she passes Anchorage, Alaska.

Tyee has become a large adult. She weighs 21 pounds, and is two and one-half feet long. She has a blue-green back and silvery-white belly. The two-tone coloring helps to keep her enemies from seeing her. Seen from above, she blends with dark ocean waters; from below, she blends with the lighter sky.

By now, she knows sea lions by sight and smell. She has been chased by them often, as well as killer whales. But she survives. Tyee the Lucky.

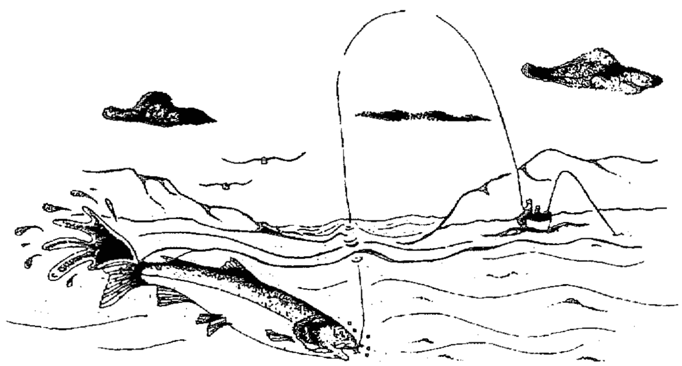
During July of her third year in the ocean, Tyee turns around and heads south. Her trip back down the coast is farther out to sea, about 200 miles. She is heading back to the Columbia River. As if she was hearing some natural music that only salmon can hear, Tyee knows where to go. She is swimming with the current now, and is able to cover about 30 miles each day.

Not all kinds of salmon stay in the ocean three years. Each one has its own time of return to fresh water. Sockeye and steelhead trout stay two or three years. Coho salmon stay for a shorter time. Chinook may stay in the ocean as many as five years before heading back upriver, but most stay two or three years.

Not all Chinook enter the rivers at the same time of year. There are spring, summer and fall Chinook. These *runs* of Chinook are named for the time they enter the river from sea.

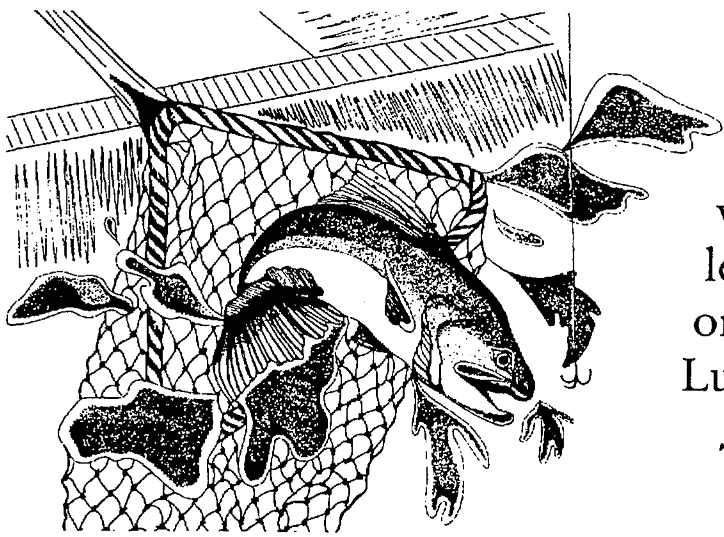
Tyee is a spring Chinook. Just before Easter in her third year at sea, she returns to the Columbia River mouth and enters. Firm and plump, with pink meat, she is at the prime of her life. She weighs 28 pounds and is almost three feet long. She is not the biggest fish there, but she is large. She carries scars from her adventures in the ocean. Behind the large fin on her back are tooth marks from a sea lion that just missed. A row of sea lice clings to her body, but she is strong and healthy.

As Tyee moves up into the estuary, she does not know that a short *gillnet* season just ended. Once again, she avoids danger from people's nets. But she is not through with people just yet.



Sport anglers are fishing in a number of "hot spots" in the upper estuary. Tyee would be a prize catch.

Tyee snaps at an anchovy. The anchovy has two hooks in it. A line is attached. Her first reaction is to dive deep and to swim away from the pull of the line. This sets the hook even deeper in her jaw.



Her deep dive doesn't seem to work. She rises to the surface, slashing and twisting. She jumps out of the water twice to rid herself of the hook. When she rests, she can feel getting pulled closer to the boat. She dives again, then rises, trying to get loose. The hook is working loose. If she has enough strength left, she may be able to keep the fight going.

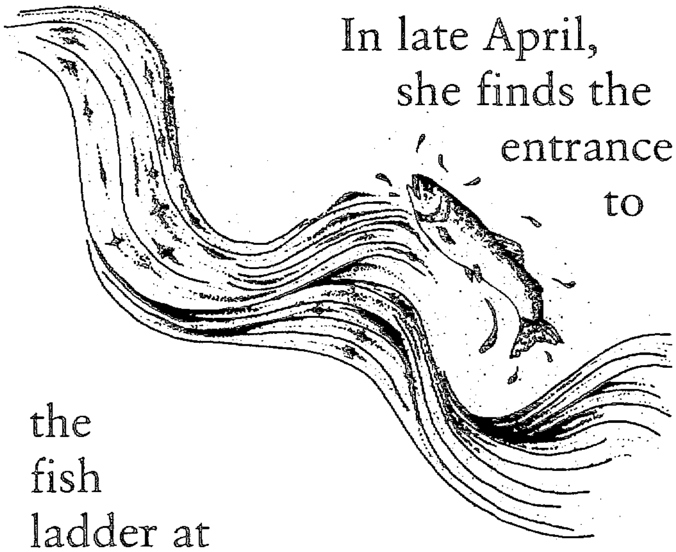
After 20 minutes, Tyee is very tired. Perhaps her luck has run out. The boat is close now. She can see a large silver hoop with green nylon netting moving towards her. With one mighty leap and a twist of her body, Tyee rises out of the water. The hook tears loose. She lies on the surface for a moment, then rolls and swims down with what little strength she has left. She becomes "the big one that got away". Tyee the Lucky.

THE RACE TO THE REDD

Tyee wastes no more time in the lower Columbia River. The rains have swelled the river, urging Tyee in a race upriver. Against the current, she has one purpose - to get back to her home stream and spawn. Eggs are growing inside of her.

She is no longer interested in food. Even though she might snap in anger at an angler's bright lure, she is not hungry.

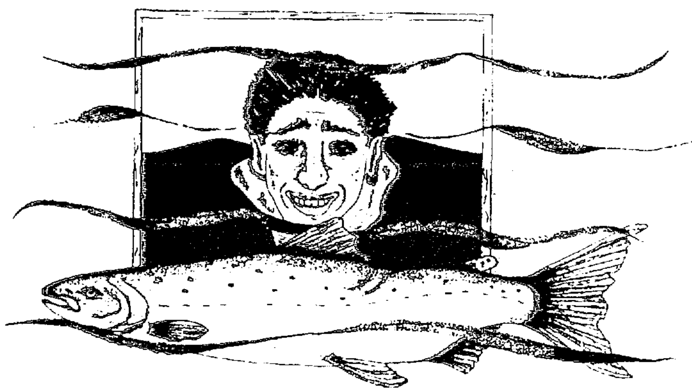
She has stored up enough energy to make it all the way to Idaho. Now, it is time to use that energy.



In late April, she finds the entrance to the fish ladder at Bonneville Dam. She climbs the stairs of water. She passes an underwater window where a human counts her as chinook number 61,346. There will be more chinook behind her.

She passes into the reservoir. The slack water confuses her for a time, but she finds the ladder at The Dalles Dam. Along the way, there are more anglers and nets. She avoids both, but continues to use her energy reserves and gets thinner.

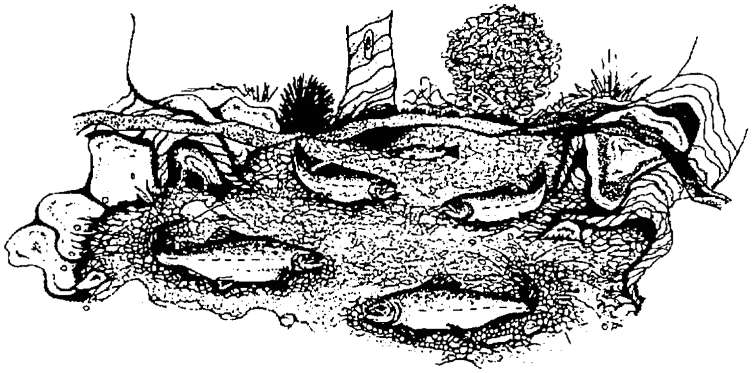
As she passes forks of rivers and streams, she uses her homing instincts to show her the way home. She says "no" to the Deschutes, the John Day and the Umatilla. But the Snake River "smells" right to her, and she leaves the Columbia. One hundred and fifty miles later, she comes once again to the Salmon River. She waits a few days for rain to make the river "right". Inside her, eggs are ripening. Her stomach is empty from not eating for a month.



Tyee finds the Middle Fork of the Salmon and turns into it. A week later, she finds her creek without a name. After traveling about 900 miles downstream, 4,000 miles in the ocean, and another 900 miles to return here, she has returned home with a precious cargo.

A five-foot waterfall is all that stands in the way of reaching her goal. After all that's happened, it seems impossible that Tyee could leap twice her length. But she does.

Four of her redd-mates have already arrived. She is the last. Only nine adults from the original 750 fry made it back to the Columbia River. Two of those ran into a gill net, and couldn't back out. Another was caught by an angler's hook. And another became confused by a dam and died of exhaustion trying to find a way through the concrete.



The five are not only the luckiest, they are also the fittest. They alone will pass on these traits to the next generation of chinook.

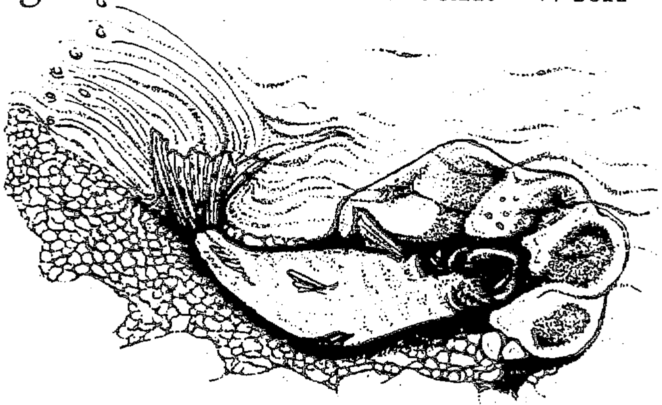
THE FINAL ACT: SPAWNING

Males and females pair off to spawn. There are three males and two females, so there is much chasing and nipping as the males try to get a good position around the females. One of the chinook males is a jack. Jacks return to spawn earlier than other adults. He's smaller than the other males, but he is able to spawn if the full-sized males don't make it back to the spawning area.

The big males are dark and blotchy and have hooked snouts. They think the jack is nothing but a bother. When he drifts into the territories they have set up, they send him scampering upstream. After a while, he gets the idea that he is not wanted here.

Tyee ignores all this action. She has her own job. She builds a redd.

She chooses a spot where the gravel is fine and clean. With



her tail, she begins sweeping gravel aside. She scoops out a kind of trough, in the shape of her body and twice as long. She tests it by settling into the trough. Then she moves upstream and swishes more gravel around the redd until it feels just right. The redd has a ridge on the downstream edge where she can rest.

Meanwhile, the two males begin a courtship "dance" around Tyee and the other female. They circle slowly. They come close and move

away again. This goes on for hours around Tyee and her sister, resting in their redds.

Finally, a male swims beside Tyee and just upstream from her. His body presses hers against the ridge of the redd. Both seem to shudder. Tyee trembles. Pink eggs come out of her and drift into the redd. Almost immediately, a white cloud of sperm, or milt, comes out of the male and covers the eggs. This fertilizes the eggs, beginning the whole cycle again.

Tyee, with one last tired effort, rises from the redd. Just upstream, she swishes her tail. The action of her tail lifts small pieces of gravel from the bottom and into the redd. Fine gravel now covers and protects the eggs.

Leaves on the trees on the stream banks are yellow and brown. It has been five years since our story began. Tyee the Lucky has finally come home. In a few days, she dies. Her body decomposes, providing food for the smaller animals in the stream that she once fed on as a fry.

With death comes life. The journey of Tyee the Lucky is complete.