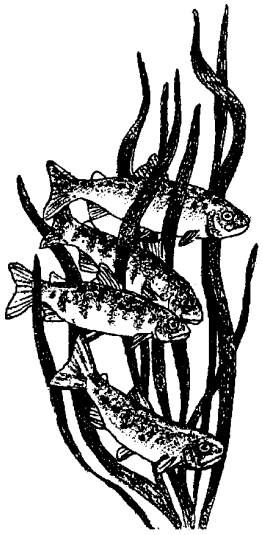
Pacific Salmon: Species in the Spotlight, and Salmon Cycles

Key Concepts

1. Pacific salmon include seven species of fish with an anadromous life cycle. This life cycle enables them to take advantage of important habitat resources in very different places.

2. Salmon populations which return to spawn at the same time and place are reproductively isolated from other members of their species. These breeding populations, known as stocks, are uniquely adapted to the specific conditions of their spawning stream.

3. Salmon's requirements for fresh water spawning habitat have made them highly vulnerable to our uses of the land adjoining rivers, streams, and other wetland environments. Outside of Alaska, wild salmon stocks are at risk in all parts of their U.S. range.



Background

In the Pacific Northwest salmon are synonymous with controversy. These fish support an important commercial fishery and a significant sport fishery. Arguments have flared for years over allocation of the resource, between commercial fishers and sport fishers, Indian and non-Indian fishers, even between U.S. and Canadian fishers. Yet today as never before, the very survival of the salmon is at issue. Certainly the destruction of the salmon benefits no one. However, growth in human population and resource demands made by agriculture, forestry, the hydroelectric industry, and land development are putting unprecedented demands on the habitats salmon require to complete their life cycles.

Complete life histories of the salmon species and an in-depth treatment of the controversies surrounding these fish are beyond the scope of this guide. Resources listed in the Bibliography section provide additional information.

Materials

For each student:

- "Species in the Spotlight" student reading
- "Salmon Cycles" activity sheet
- one sheet of blank paper
- scissors
- glue

Teaching Hints

"Species in the Spotlight" and "Salmon Cycles" provide some background on the biology and the issues necessary to understand current status of these remarkable fish.

"Species in the Spotlight" is a very long reading. While you may opt to assign it as individual work, directions for cooperative interpretation of the text are suggested below.

1. Divide the class into 5 groups. Assign each group a section of the reading. They may choose to take turns reading aloud or they may prefer to read silently.

   The following is a suggested division of the reading:

   Student #1 reads Parts 1-2, questions #1-2.

   Student #2 reads Part 3, questions #3-6.

   Student #3 reads Part 3, questions #7-10.

   Student #4 reads Parts 4-5, questions #12-13.

   Student #5 reads Part 5, questions #14-17.

2. Ask each group to work together to write the best answers they can to the questions in their assigned reading. Make it clear that this is not a time simply to copy another student's work; soon, each student will have to help others who have not read that section write answers to questions about the text. All the students must both ask for help in understanding their assigned reading and questions and offer help to others when they have an idea. This is an opportunity to share the workload and help each other.

3. When the groups have finished their work, form new groups in which each team member has read and studied a different section of the reading. Each student must share with the others his or her section and help his or her team answer the questions. Again, this is not a time to simply copy answers. All students in the class will be asked to complete a review activity independently. This time in the new teams is an opportunity to learn from others or help teach others the life cycle of the salmon and issues about managing salmon. If a team member is confused, this is an opportunity to get help and if a team member understands something clearly, this is a chance to cement that understanding by teaching someone else.

4. Use the activity sheet "Salmon Cycle" as review. Use it as a check for understanding of the preceding group work. Provide students with scissors, glue and a blank sheet of paper for compiling their work.

Key Words

alevin - larval salmon whose yolk sac has been depleted

anadromous - fish which live part of their lives in fresh water and part in salt water

clearcut - the logging practice of removing all trees from a timber harvest area

Endangered Species Act - national legislation enacted in 1973 which requires protection of species threatened with extinction

fry - in this case, young salmon in fresh water

hydroelectric - pertaining to the use of falling water (e.g., from dams) to generate electric power

magnetic field - energy field around the earth which causes magnetic objects to orient themselves toward the north and south magnetic poles

milt - the sperm containing secretion of the testes of fish

parr - young salmon in fresh water characterized by dark bars on their sides

polarized light - a state in which rays of light exhibit different properties in different directions, such as when light is reflected from or passes through the surface of water

redd - gravel nest built by female salmon for depositing eggs

salinity - a measure of the salt concentration in a solution

salmonid - member of the fish family Salmonidae, including salmon, trout, chars, and whitefish

salmon stock - breeding population of salmon which is reproductively isolated from other members of its species, often highly adapted to a specific stream. Though isolated, stocks are still capable of interbreeding with others of the same species.

smolt - young salmon in transition between fresh water and salt water habitats

spawn - to deposit eggs and sperm directly into the water, as in fish, where they fertilize and begin the life process

species - basic category of biological classification composed of related individuals that resemble one another, are able to breed among themselves but are not able to breed with members of another species

yolk sac - a sac attached to an embryo within an egg or to a recently emerged larva which contains the food needed by the organism until it can eat on its own

Extensions

1. Conduct a survey of a local stream to compare its habitat characteristics with the freshwater needs of salmon. Consult the lessons in the section "Water Quality Monitoring" for instructions on water quality tests for dissolved oxygen, pH, and temperature. Use the sample stream survey form included as the last page of these teacher pages, or design your own.
2. Have your students research the history and current status of the Endangered Species Act. Contact a regional office of the National Marine Fisheries Service or the U.S. Fish and Wildlife for a list of all species on the list, or call your state's Department of Wildlife for information on endangered species in your state.
3. Engage your students in the versatile "Fish Banks" simulation in which teams of students manage their fishing companies to maximize their assets. The simulation, which has received rave reviews from teachers and students across the country, is available from Fish Banks, Ltd., University of New Hampshire, IPSSR-Hood House, 89 Main Street, Durham, NH 03824-3577.

Answer Key

Species in the Spotlight

1. Students may not yet have the background to be able to answer this question in depth, however they should be able to think of at least one example. Cutting back the number of days fishers may fish is a way of asking this group to pay such a price. Other examples might include restricting logging or development along streams used by salmon. If your students have played the Boundary Bay Game, encourage them to think about the kinds of prices people paid in that game.

2 a. Anadromous means beginning life in fresh water, migrating to salt water for part of the life cycle, and returning to fresh water to reproduce.

b. Migration may allow the fish to take advantage of important food and habitat resources in different places.

3 a. Alevins still retain a portion of the yolk sac, their food source inside the egg. They need no other food until the yolk is absorbed.

b. Fry no longer have a yolk sac and must find their own food.

4. A salmon can control the salt balance in its body by expelling excess salt when it is in a salt water environment, but retaining salt when it is in freshwater. A fresh water fish like a catfish can maintain its salt balance in fresh water but not in sea water.

5. Coho and Chinook salmon have well developed teeth and feed on small fish. Chum, pink and sockeye have gill rakers specialized for feeding on plankton.

6. The return migration requires an enormous output of calories. Since salmon stop eating when they return to freshwater, they depend entirely on the energy stored in their bodies to get them home to their place of origin. Oils and fats are energy (calorie) rich.

7. Salmon can detect changes in temperature, salinity, polarized light, magnetic field of the earth, and odors in the water.

8. When water is diverted for irrigation, spawning channels may not have enough water left to support eggs or young fish.

   a. It is necessary for salmon to lay so many eggs because they have a high mortality rate; many things cause the demise of individual eggs, juveniles and adults before reproduction.

   b. Answers will vary but will include sources of mortality listed chronologically in Part C below.

   c. Specific hazards at each life cycle stage include: eggs and alevins may be washed out of the gravel by heavy rains, smothered by debris in the stream, desiccated, or eaten by scavengers.

   Fry may be preyed upon by larger fish, birds and mammals. They may also suffer death or injury passing through the turbines of power dams, or die from insufficient water or poor water quality in streams.

   Smolt are preyed upon by a variety of fish, birds and mammals. They also suffer from destruction of estuary habitats through development.

   Adult salmon are eaten by marine mammals and harvested by humans.

   Spawning adults are preyed upon by eagles, bears, humans, etc. They are blocked by dams and water diversion projects. They may also fail to spawn if stream conditions have been altered.

10. Northwest forests might suffer from a loss of soil fertility.

11. Salmon stocks are isolated and genetically different from one another. They represent a group of fish which is adapted to a specific stream and different from stocks spawning in other streams. If a stock goes extinct, it may not be replaced by salmon of the same species but from a different stream.

12 a. The invention of canning triggered the over-fishing of Pacific salmon around the turn of the century.

   b. Before the invention of canning, there was no advantage to catching more fish than could be eaten fresh locally. After that, canned Pacific salmon could be eaten by people all around the world.

13. The giant Elwha Chinooks were an isolated stock which went entirely extinct when the dam was built, so there is little chance they will return. Other Chinook salmon will probably colonize the river, and after many

generations, they may develop some of the characteristics of their predecessors.

14. Clear-cutting endangers salmon by:

a. promoting siltation of streams from erosion of hillsides;

b. raising stream temperatures; and

c. increasing the risk of predation, through loss of the cover of trees overhead.

15. Five threats to salmon not present 200 years ago include:

a. over-fishing,

b. dams,

c. damaging forestry practices,

d. diversion of water for agriculture and industry, and

e. by development in areas salmon need for their reproduction.

16. None of the 214 stocks is entirely out of danger.

17a. People are waking up to the threatened status of salmon in the Pacific Northwest, and they are making efforts to protect them at a local level.

b. Salmon are extremely adaptable fish. If we provide a place for them, they are likely to return.

Salmon Cycles

Key will have pictures arranged in correct order with names and hazards as follows:

Eggs—heavy rains, streams drying up, smothering by silt, stepped on, eaten by scavengers, poor water quality, temperature changes

Alevins—heavy rains, streams drying up, smothering by silt, stepped on, eaten by scavengers, poor water quality, temperature changes

Fry—preyed upon by larger fish, birds and mammals, turbines of power dams, lack of water, poor water quality

Smolt—preyed upon by larger fish, birds and mammals, destruction of estuary habitats through development

Adult salmon—preyed on by marine mammals, harvested by humans

Spawning adults—preyed upon by eagles, bears, humans, etc., blocked by dams, water diversion projects, and development

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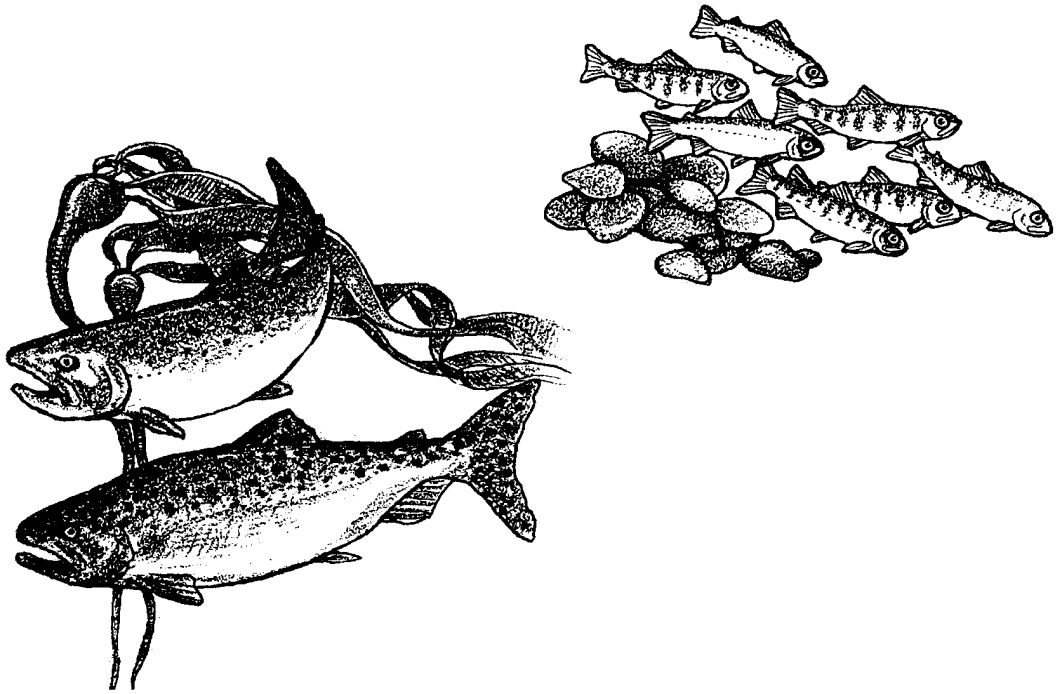


Part One: A Northwest Treasure

For millions of years, the creeks and rivers of the Pacific Northwest teemed with salmon. They appeared each year in immense numbers, each species at its own time and place. Their appearance was part of the salmon's remarkable migration from fresh water to the ocean and back again, to complete their life cycle. The salmon runs of today are only a small remnant of the enormous runs which passed through the waters of the Pacific Northwest little more than a century ago.

Salmon have been important to people living along Pacific Northwest shores and stream banks for thousands of years. Before the arrival of Europeans, Indians up and down the Pacific coast centered their economy and their culture on the arrival of the salmon, and salmon are still important to Native American cultures today.

With the arrival of white settlers, the salmon fishery became a major industry of the Pacific Northwest. More recently the fishery has declined, and the growth of other industries has overshadowed the economic importance of the salmon fishery. Yet today salmon are very much in the spotlight. Fisheries biologists have discovered that nearly all naturally spawning salmon runs in the U.S. are fighting for their very survival. The question of the day is how to protect them -- and at what price.

1. What might be a price someone would have to pay to protect salmon? (Hint: Keep in mind that a price doesn't necessarily mean that someone pays money.)

Part Two: Some Salmon Natural History

Pacific salmon are members of the fish family Salmonidae, along with trout and Atlantic salmon. Sometimes you will hear members of this family referred to as "salmonids". Scientists think the advance and retreat of continental glaciers over much of North America during the Ice Ages was a factor in separating the Salmonidae into the many species we have today. Although the Atlantic coast has only one salmon species, the Pacific Northwest is home to seven. Chinook, coho, chum, sockeye, and pink salmon are the original five Pacific salmon species; more recently scientists have reclassified steelhead (sea-going rainbow trout) and sea-going cutthroat trout as Pacific salmon as well. All seven are in the genus ***Oncorhynchus***.

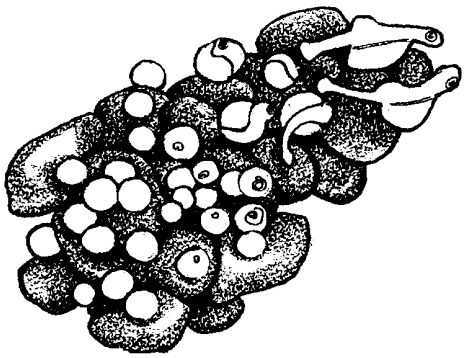
Most members of the salmon family are "anadromous", meaning they spawn (lay their eggs) in fresh water but live much of their lives in salt water. Some scientists believe salmon originated from fresh water fish. If this is true, the anadromous lifestyle has given salmon access to an abundant food resource in the ocean. Other scientists think salmon may have arisen in the ocean. In this case an anadromous lifestyle allowed them to take advantage of protected fresh water habitats to rear their young. Not all salmon migrate, however. Some species, such as the rainbow trout, are capable of migrating to salt water but they may also stay in fresh water their entire lives.

2 a. What does the term "anadromous" mean?

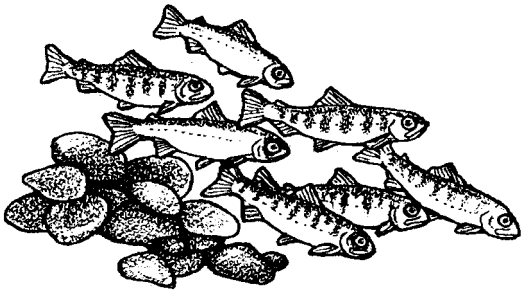
b. How might a fish benefit from being anadromous?

Part Three: Salmon Life Cycle

Life for salmon begins as eggs, hidden beneath the clean gravel bottom of a quickly flowing stream. Bathed by a strong, cold current, tiny larval fish slowly develop inside the eggs.



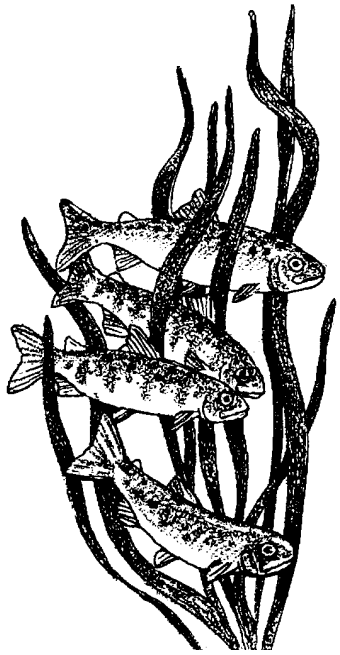
Although protected from sight, many of these eggs will not mature. Changes in water flow, disturbance by humans and other animals, and changes in temperature and water quality all take their toll. After a number of weeks the eggs which survive hatch into small transparent fish called “alevins” (a-lu-vuns) which still carry their food supply in a yolk sac. Alevins remain hidden beneath the gravel, nourished by their yolk for several more weeks. When they finally emerge from the gravel they have transformed into quick silvery fish that must now find their own source of food. At this stage they are called “fry” or “parr”.



3 a. Why don’t alevins need to eat?

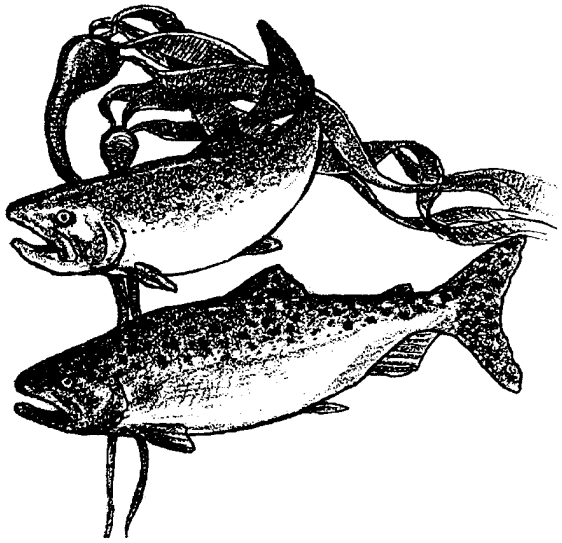
b. Why do fry need to?

In some species the fry move to salt water almost immediately, while in other species they live in fresh water for a year or more. In one species, sockeye salmon, the fry migrate to a fresh water lake where they will live for one or two years or more. For this reason sockeye only spawn in a river which is connected to a lake. Fry feed on fresh water plankton and insects, and in turn are food for larger fish, birds and mammals.



Salmon pass through the next stage of their lives, called the “smolt” stage as they enter salt water. Smolts are young salmon whose bodies are adjusting to a salt water environment. This is an interesting problem for a fish. The fluids in its body are saltier than fresh water but not so salty as saltwater. When the fish is in fresh water it must prevent salt from leaving its cells, but when it enters salt water it must prevent excess salt from entering its cells. Salmon are among the few fish which can change the direction their bodies pump salt to maintain a constant salt balance within their cells.

4. Why can salmon survive the change from fresh water to salt water while a catfish could not?



Once in sea water, the young salmon may feed in the protected water of the estuary for several weeks, but eventually nearly all seagoing adult salmon leave on an extended migration which may take them thousands of miles from their river of origin. Most salmon stay at sea for two to six years and some migrations are longer still. Until recently, little was known of their behaviors in the ocean. Today, new technologies are improving our ability to label individual fish and track their movements in the North Pacific.

Chum, pink and sockeye salmon feed on plankton, such as small shrimp and other tiny animals. They swim with their mouths open, scooping in plankton and straining it from the water with special structures called gill rakers, projections from the skeleton near their gills. Coho and Chinook salmon, with their well-developed teeth, feed on larger prey such as herring. In the ocean, salmon are preyed upon themselves by larger fish, marine mammals, and humans.

5. Many scientists believe coho and Chinook salmon are more closely related to one another than they are to such species as chum, pink or sockeye. What evidence might suggest that?

With the onset of sexual maturity, salmon begin a remarkable migration homeward. The powerful muscles which we know as rich, oily flesh are, for a salmon, the return ticket to the stream of its origin. This stored energy is critical, not only because the salmon need a lot of energy to make their long journey, but because, when salmon return to freshwater, they stop eating. Returning salmon travel swiftly, averaging 30-40 miles a day. In rivers and streams, salmon are legendary in their ability to climb rapids and leap cascades. Some salmon are such masters of endurance that they can travel more than a thousand miles inland to spawn.

6. Oils are a fish's way of storing energy. Why do salmon need to store so much energy in their oily flesh?

Salmon generally return to the same stream where they began their life. How do they find their way back such vast distances from their ocean feeding grounds? We know that salmon are sensitive to changes in temperature and salinity (the salt content of sea water), to polarized light, and even to the earth's magnetic field. Presumably these cues help guide the fish toward the river. Near the river the salmon's powerful sense of smell is called in to play. Each stream has a unique chemical composition, and as salmon enter fresh water they are able to locate their precise place of origin by trace odors in the water.

7. What environmental cues are salmon able to detect which might help them navigate back to their home stream? (Name at least four.)

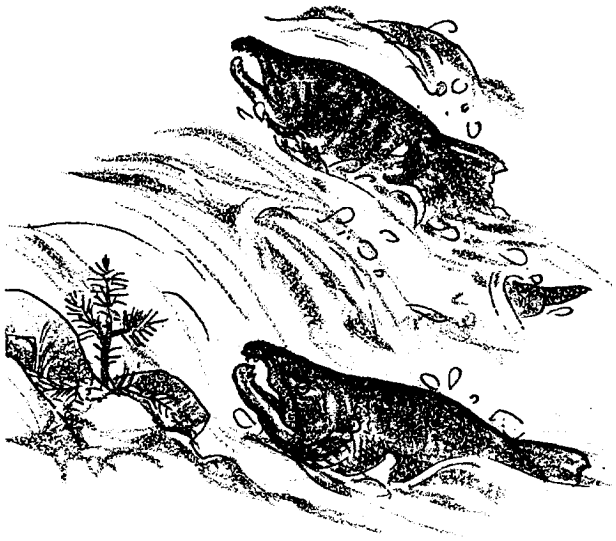
   a.

   b.

   c.

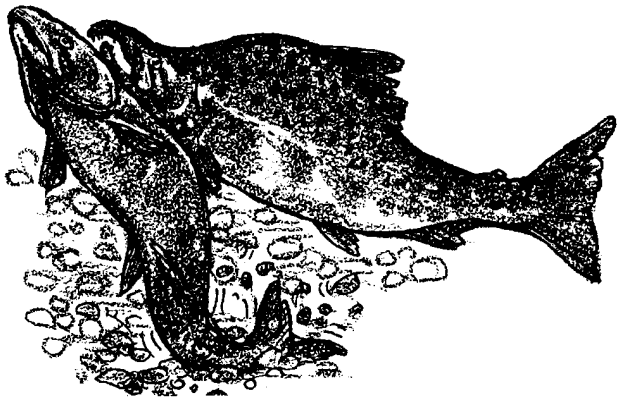
   d.

As the salmon enter fresh water many changes take place in their bodies. The fish no longer feed, but exist solely on fats stored in the muscle tissues. Each species develops distinctive colors and features, such as a hooked snout on male chum salmon, a humpback on male pink salmon, and the brilliant red color on the backs of sockeye. These features aid the fish in recognizing others of their own species, and in territorial behaviors and courtship activity as the fish near the spawning beds.



Each species of salmon seeks out slightly different stream conditions for spawning. However, all species require a well-shaded river or stream, cool water temperatures (below 65° F.) and a loose gravel bottom. Spawning areas tend to lie in shallow riffles, places where there is some gentle water movement that makes dissolved oxygen in the water plentiful. Many salmon spawn in water so shallow it doesn't even the backs of the adult fish.

8. Quick flowing, shallow rivers and streams offer a good supply of oxygen for developing eggs, but they also have risks. What might be a survival threat to the eggs in areas where we use water supplies such as this for irrigation?



While the male hovers nearby and fends off other males, the female uses her tail to make a depression in the gravel called a "redd". The male and female hover over the redd, releasing eggs and "milt" (sperm). Once fertilized, the eggs stick firmly to the gravel. The female then moves upstream where she pushes more gravel over the eggs and at the same time, prepares another redd. Depending upon the species, a female salmon will lay anywhere from 2,000 to 7,000 eggs.

9. From each pair of spawning salmon, it takes just two returning offspring to continue the population.

   a. Why is it necessary for salmon to lay so many eggs?

   b. What might be some sources of mortality (death) in salmon between the time the eggs are laid and the time the salmon developed from those eggs spawn?

   c. What are some specific hazards a salmon faces in each of its life cycle stages: egg, alevin, fry, smolt, adult, and spawning adult?

Most Pacific salmon species die soon after spawning. (Steelhead and cutthroat trout as well as Atlantic salmon are an exception. These fish often survive several spawning cycles.) Death in Pacific salmon species occurs through a rapid breakdown of the salmon's body, as though the aging process was suddenly speeded up.

We might wonder why Chinook, coho, chum, pink and sockeye should be programmed to die after one spawning cycle, while their close relatives the steelhead or the Atlantic salmon are not. There are several theories. Here's one: perhaps the carcasses of the adults offer a benefit for the next generation. Some scientists think the death of spawning adults in these salmon species may have arisen in response to the glacial conditions in which they evolved. As glaciers retreated, a barren landscape was exposed with little soil to

support new vegetation. When salmon migrated upstream and died, their carcasses brought essential nutrients to the mountainsides, helping reestablish the forests which are a crucial part of the salmon's fresh water habitat. In this way the death of adult salmon may have helped assure the survival of the next generation.

10. If this theory is true, how might Pacific Northwest forests be impacted as salmon runs disappear?

Part Four: Salmon Stocks

To understand the crisis of salmon in the Pacific Northwest today, one must learn one more fact about their biology. Salmon return to a specific stream at a specific time of year and spawn with other salmon that originated nearby. Because of this behavior, groups of salmon which spawn together have become isolated from salmon spawning in other streams or even in the same stream but at different times of the year. Scientists refer to these isolated populations of salmon as "stocks". Over thousands of years, genetic changes within each "stock" of salmon have caused it to become finely adapted to the specific conditions of the stream in which it spawns. If a stock were to go extinct, salmon of the same species but from another stream may be too different to replace the population which was lost.

11. The Endangered Species Act was written to protect species threatened with extinction. Recently courts have been asked to protect endangered salmon **stocks**, such as the Snake River sockeye. If the sockeye salmon species is not considered endangered in other rivers, how is it that **these** sockeye are receiving special protection under the Endangered Species Act? (If the Endangered Species Act was written to protect species, why do you think protection is being given to a stock rather than the species as a whole?)

Part Five: Salmon at a Crossroads

Before settlement of the Pacific Northwest by people of European descent, salmon had been harvested as a primary food source by Native American peoples for many thousands of years. Indians made few changes to the spawning habitats of the salmon, and Indian populations were stable, so Pacific salmon were not at risk.

After the arrival of Europeans, new techniques of fishing appeared, as well as the invention of canning as a method of food preservation. With new markets for canned salmon across the country and around the world, fishing became extremely profitable. By the end of the 19th Century the waters of the lower United States had already become seriously over-fished. Regulations on fishing were eventually put into place, but soon other developments began to threaten the salmon's freshwater habitats.

12 a. What change in the technology of food preservation triggered over-fishing of Pacific salmon around the turn of the century?

b. Why did it cause more fish to be harvested than before that time?

Early in the 20th Century, hydroelectric dams appeared along most of the Northwest's major rivers. Many of these dams were built with no provisions for salmon, so all salmon stocks which spawned above them were lost. As an after-thought, salmon hatcheries were added, but the fish raised in them were often stocks from other rivers. Only in recent years have the true costs of these mistakes been acknowledged. In a few regions, older dams may actually be removed, but in most areas, the hydroelectric power and the flood control they provide are worth more economically than the salmon which might be reintroduced.

13. The Elwha River on Washington's Olympic Peninsula once supported a stock of giant Chinook salmon, weighing between 50 and 100 lbs. When a dam was built on the river, the entire stock of fish was lost because it spawned above the dam. Plans are now underway to remove the dam. Some people ask if the giant Chinooks will return to the Elwha River. What do you think? Explain your answer.

Forestry has been a mainstay in the economy of the Pacific Northwest for over a hundred years. Early logging practices used streams to transport logs and were devastating to spawning beds, but more recent practices have not been much better. The erosion from clear-cut hillsides and from logging roads causes silt and logging debris to enter the stream and bury the spawning beds of salmon. Logging also eliminates shade over streams, raising water temperatures and leaving fish exposed to predators. New laws require leaving

a corridor of trees along all streams that still support salmon, but such measures may be too little, too late.

14. Until recently, clear-cutting, the timber harvest practice of removing all trees from an area, has been widespread in the Pacific Northwest. What are three ways it endangers the survival of salmon?

    a.

    b.

    c.

Fresh water itself has become a contested resource, and salmon are often the losers. Water is in demand for irrigation, for industry, for navigation, for population centers, and of course for hydroelectric power. Decisions about how water will be used can have a major impact on people's jobs. In an arena with powerful interests and where emotions are strong, salmon have few advocates.

Finally, salmon are threatened simply by the sheer numbers of us who want to live and work near the water. As we put critical wetland habitats to our own uses to build homes, shopping centers and work-places, habitats essential to salmon are destroyed.

15. What are five threats to the survival of Pacific salmon which did not exist 200 years ago?

    a.

    b.

    c.

    d.

    e.

In 1989, a team of fisheries scientists led by Jack E. Williams made a survey of naturally spawning salmon stocks in California, Oregon, Idaho, and Washington, to decide how many were at serious risk of extinction. They looked at threats such as expected changes to the fish's habitat, over-fishing, disease, and competition from other species. The results of this study were startling. Out of 214 stocks identified, the scientists grouped them as follows:

101 stocks -- at high risk of extinction

58 stocks -- at moderate risk of extinction

54 stocks -- of special concern

1 stock -- classified as threatened under the endangered species act

16. Of the 214 stocks of salmon stocks which were part of the Williams survey, how many were determined to be entirely out of danger?

Clearly, these remarkable fish are facing the fight of their lives. But they do have two things going for them. One is that people in the region are becoming much more aware of their threatened status, and many citizens are now making an effort to protect salmon locally. Schools, community groups, Indian tribes and government agencies are working hand in hand to improve salmon habitat within their communities, through stream enhancement projects, habitat restoration, and public education.

The second advantage they have is the salmon's own resilience. Their ability to persist against formidable obstacles and adapt quickly to new situations is the only reason salmon are still with us today. If Pacific salmon are to survive as wild fish into the next century, it will be out of a combination of their own resourcefulness and our determination to protect them.

17. What are two reasons to be hopeful that wild salmon can be saved?

a.

b.

Salmon Cycles

1. Cut out each of the pictures on the next page.

2. Arrange them on another sheet of paper in the correct order to illustrate the cycle of life of the Pacific salmon. Glue the pieces in place.

3. Label each life stage.

4. On the outside of the circle, list all the survival hazards faced by the salmon during each phase of its life. You should have a list for each life stage.