US Army Corps
of Engineers
North Pacific Division

Salmon Passage Notes

Snake and Columbia River Fish Programs
Special Issue

Columbia River and Salmon– A Brief History

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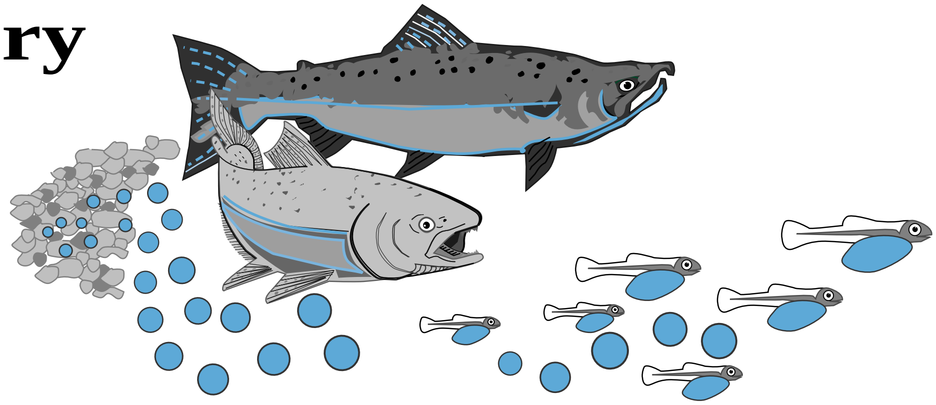


The Columbia River pours more water into the Pacific Ocean than any other river in North or South America. In its 1,270 mile course to the Pacific Ocean, the Columbia flows through four mountain ranges—the Rockies, Selkirks, Cascades, and coastal mountains—and drains 258,000 square miles. Its largest tributary, the Snake, travels 1,038 miles from its source in Yellowstone National Park in Wyoming before joining the Columbia.

This vast river basin was formed near the end of the last Ice Age, 12,000 to 19,000 years ago, by the Bretz Floods. Immense ice dams half a mile high held back melting ice, creating a huge lake in northwest Montana, called Lake Missoula. Each time the ice gave way, massive walls of water as high as four hundred feet hurled boulders and icebergs seaward with a great destructive force. These floods generally followed the route of the present day Columbia River and came at least 40 times.

Judging by fossil remains, salmon and their ancestors have been running in Northwest rivers for at least five million years. When the glaciers were at their latest advance it is believed Pacific salmon survived in two refuges, one each on the North American and Asian continents. When the glaciers retreated 10,000 years ago, the salmon dispersed and recolonized millions of miles of rivers draining into the North Pacific.

Wild Pacific salmon are anadromous, which means “up-running”. They begin their lives in freshwater streams, then, as smolts, travel to the ocean where they spend two to five years. They return to the place of their births to spawn and, except for steelhead, die after spawning once. Bear, otter, eagle, osprey, and others glean spawning and spawned-out salmon from streams and distribute the fish’s nutrients throughout the forest.

Salmon begin their lives as pea-sized, pink eggs buried in the gravel of free flowing streams. The fish hatch after approximately 50 days and within 18 months they begin their migration to the sea. Usually, as they begin their migration, the young fish begin smoltification—a physiological transformation that enables them to adapt to salt water.

Timing of the smolts’ migration can be affected by changes in light and temperature as well as water flow. Size and condition of the fish also is a factor. They travel mostly between dusk and dawn, when they are not as visible to predators. Their journeys down freshwater streams often encompass many hundreds of miles—some travel nearly a thousand miles.

During their ocean phase the salmon grow rapidly, sometimes reaching in excess of 50 pounds feeding on abundant food supplies. They return to the waters of their birth to spawn, following the reverse sequence of the trip to the sea. Their in-stream and nearshore courses are probably set by an ability to discern the direction of river flow, to sense temperature changes in the water, and to detect combinations of smells from distinct watersheds. A salmon probably can detect one part per trillion by smell.

Although steelhead can live to repeat this cycle, Pacific salmon generally do not eat during their upriver trek, and they die soon after spawning. As their bodies transition from salt water to the freshwater of their birth, they change from sleek, silver swimmers into humpbacked aggressors, their bright ocean sheen replaced by mottled shadings to disguise them in the shallow waters.

Through tagging, scientists have found that no matter where salmon wander, they find their way home. In one study, marked fish in the Aleutian Islands subsequently were recovered in their native stream in the Columbia River system 2,000 miles away. Salmon generally will not spawn in locations other than their birthplaces. If they encounter an insurmountable obstacle along the journey to their home stream, they may die attempting to overcome it.

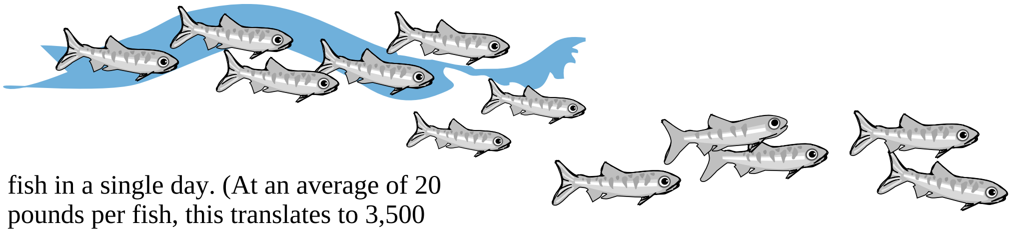
Since ancient times salmon have shaped the cultures of the region. They supplied an abundant food source to the Native Americans living in the Columbia River Basin. Before the coming of Europeans, a native family, by working diligently during the salmon season, could store in a few months enough fish to meet its basic food requirements for a year. There were supplemental foods, but the fundamental food resource was salmon.

When Lewis and Clark explored the region in the early 19th century, huge numbers of fish returned to spawn every year. “The multitudes of this fish are almost inconceivable,” Clark wrote in the autumn of 1805. At that time, the Columbia and its tributaries provided 12,935 miles of pristine river habitat.

Threats to Salmon

Anadromous fish in the Columbia River System include five species of salmon (chinook, coho, chum, sockeye and pink), steelhead, shad, smelt, and lamprey. All varieties of salmon have declined dramatically since the early 19th century when it is estimated 8 to 16 million wild salmon and steelhead returned to spawn. One hundred years ago the Columbia Basin boasted the largest runs of Chinook, coho and steelhead on the face of the globe. Returns of salmon now number about 2.5 million, including known fish harvested in the ocean. About a half million of these are wild (non-hatchery) fish.

Three species of Snake River salmon have been listed as endangered. Under the Endangered Species Act, the National Marine Fisheries Service (NMFS) declared the Snake River sockeye salmon endangered effective December 1991. In fact, no sockeye returned to Redfish Lake in Idaho that year to spawn. (All sockeye salmon that have returned to Redfish Lake over the past several years have been taken for a captive breeding program.) In May 1992 the Snake River spring/summer and fall chinook were added to the list as threatened, and in August 1994 their status was changed to endangered.



Since settlers arrived in the Northwest in the mid-1800s, numerous factors have contributed to the decline of the salmon runs: over-harvesting; degradation of habitat from irrigation, agriculture, logging, mining, grazing, pollution from pesticides, herbicides, fertilizers, pulp and paper mills, and others; increased competition for food and spread of disease from hatchery stocks; dams that impede juvenile salmon when they migrate from their upriver rearing areas to the ocean, and again when they return as adults to spawn; and unfavorable ocean conditions.

Hydroelectric development presents a major threat to salmon populations. But the roots of the problem can be traced back to the 19th century, long before the first major dam appeared. Intensive salmon harvesting and degradation of habitat began more than 100 years ago.

Settlers in the Columbia Basin viewed anadromous fish as an inexhaustible resource. Commercial salmon fishing was one of the region’s earliest and most lucrative industries. In 1866 salmon canning began. During the late 19th century canned salmon quickly became popular in many parts of the world as a cheap food. By 1883 more than 50 canneries operated in the area. Forty-two million pounds of salmon were harvested on the Columbia in that year.

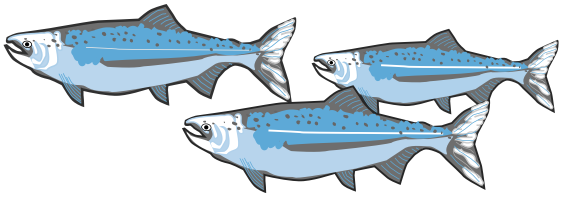
Early fishermen used gillnets, seines, traps and fishwheels. Fishwheels had large dipnets, kept in constant motion by the river’s currents, that scooped the fish into a storage bin. From their introduction in 1879 until 1934 when they were outlawed in Washington (they were outlawed in Oregon in 1926), there were at least 79 stationary fishwheels along the Columbia. One of these once took 70,000 pounds of fish in a single day. (At an average of 20 pounds per fish, this translates to 3,500 chinook salmon.) Seines, one of which once also harvested 70,000 pounds of fish in a single day, were outlawed in Oregon in 1949. The Indian harvest rate for salmon before 1850 has been estimated at 12 to 15 percent of the yearly salmon run. For the late 19th and early 20th centuries, harvest rates have been estimated at 80 to 88 percent during peak runs.

By the late 1880s harvests began to decline. Additional losses from sources other than commercial fishing accelerated after the 1920s, when some stocks had already become seriously depleted. The result was a dramatic decline in nearly all anadromous fish runs. In 1954 only seven million pounds were harvested.

Habitat destruction was a less obvious cause of fish declines. The freshwater part of the salmon life cycle depends on the quality and quantity of water in the streams, which are closely tied to the land that provides the run-off. Silt-free gravel is necessary for successful spawning. Overhanging trees provide shade assuring cool water temperatures. Chemical elements come from the river bed soils and rocks; plants and animals provide nutrients that fall into the currents. Alteration of the watershed alters salmon habitat.

As more and more people migrated into the region, pressures on fish habitat increased. Farming, grazing, mining and logging operations had increased. The rapid spread of irrigation agriculture in the arid parts of the Columbia Basin diverted large amounts of water from the rivers. Pesticides, herbicides and fertilizers made their way into the streams. Small dams hindered fish and unscreened irrigation canals drew fish onto the fields where they lay stranded.

Timber companies logged near the water, thus depriving the streams of needed shade and bank protection. With shade gone, water temperatures in summer rise, sometimes above what fish can tolerate. Road construction caused siltation along with erosion from denuded



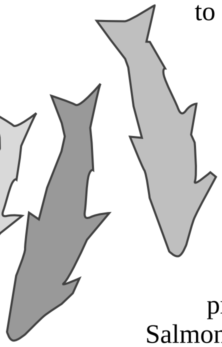
Fishwheel on the Columbia River.

hillsides. Some culverts at stream crossings created impassable barriers.

Cattle grazed at riversides which caused the banks to break down. Dredge mining tore up stream beds, flushing silt and debris into streams, destroying spawning and rearing areas. It added metallic poisons to the toxic runoff from cities and roads. In addition, pollution from pulp and paper mills has hurt salmon habitat.

During the late 19th and early 20th centuries, many biologists believed that anadromous fish populations could be sustained solely by artificial propagation in hatcheries, and at first this became the only recognized tool of fishery management. Fishery managers believed that hatcheries could replenish anadromous fish stocks without detrimental impact on the wild population.

Many biologists now believe the hatcheries have contributed to the demise of wild runs in the Columbia Basin. Large numbers of juvenile salmonids released from hatcheries compete with wild salmon for space, food and cover, and contribute to increased populations of predators. Hatchery practices tend to weaken gene pools by moving stocks from basin to basin, removing wild fish for hatchery brood stock and by disrupting the natural timing of migration. Diseases have spread as a result of poor hatchery practices.

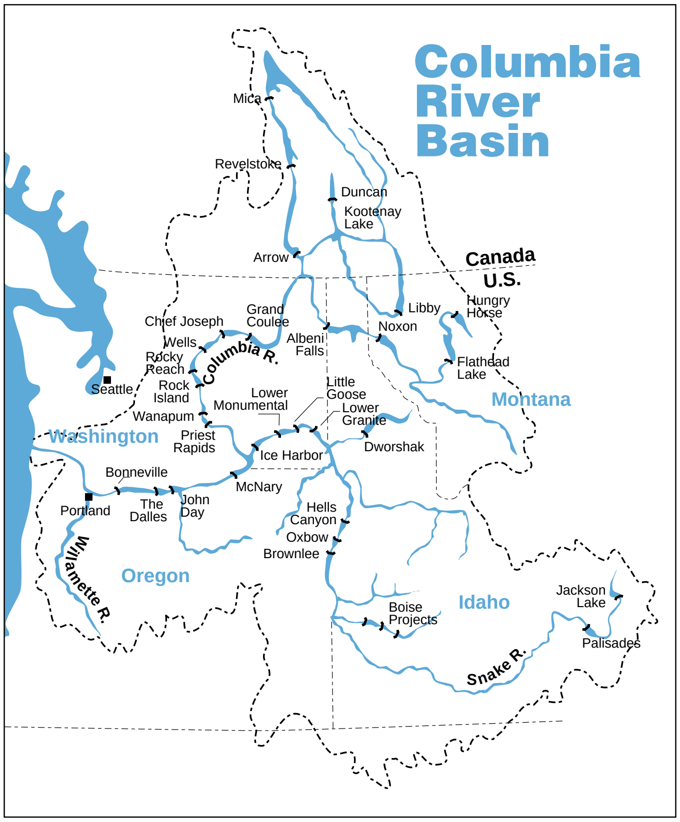


Salmon survival is affected by a variety of ocean conditions, including currents, pollution, and temperature changes such as El Nino. El Nino currents in the Pacific Ocean in recent years caused warmer water off the coasts of Oregon and Washington and attracted warm water fish far north of their usual waters, including predator fish. Research also suggests that when ocean climates shift, upwelling of nutrient-rich cold water is slowed significantly. This means less food production near the surface where fish live.

The nature of the salmon life cycle and the extensive habitat salmon require, create a complex stage for regional efforts to address salmon issues. Spawning grounds reach far upriver into privately, state and federally held or managed areas. Adults migrate into international waters where they can be caught by numerous harvesters.

Multi-Purpose River Development

No twentieth century development brought more economic benefits to the Pacific Northwest than the construction of hydroelectric projects along the Columbia and Snake rivers. Folk-singer Woody Guthrie expressed the way many Northwesterners felt about the dams when he sang, “Roll on, Columbia, roll on, . . . Your power is turning our darkness to dawn—roll on Columbia, roll on.”



In 1927 the U.S. Army Corps of Engineers, who, since 1824 has been the principal developer of the nation’s navigable waterways, began an extensive study of the Columbia River System. Workers compiled data on stream flows, topography, hydrography, geology, irrigable lands, and flood-prone areas, and produced a ten-dam comprehensive plan for the Columbia River.

In the midst of the depression, these hydroelectric projects brought jobs to a region suffering from economic collapse and extensive unemployment. Most important, the dams on the Columbia and Snake rivers provided inexpensive power to the region. Historically, Pacific Northwest residents had remained dependent on logging, farming, mining and fishing. Hydroelectric projects stimulated economic and population growth.

Completed in 1938, Bonneville Dam was the first of the mainstem federal facilities to be built and surpassed previous hydroelectric projects in terms of its size and complexity. Grand Coulee Dam, uppermost in the chain, was completed by the Bureau of Reclamation in 1942. Both Grand Coulee and Bonneville dams were designed to generate power; Grand Coulee also irrigates 500,000 acres of semi-arid land in eastern Washington. The Bonneville Power Administration was established in 1937 to market power generated by the federal projects.

Cheap, abundant electricity attracted major industries to the Northwest, including the aluminum industry, and helped in the war effort for World War II. Companies such as the Boeing Company came for the aluminum to construct aircraft, the Hanford Complex benefited from inexpensive power, and the Portland-Vancouver area became the nation’s prime shipbuilding area during the war.

As these wartime industries flourished in the Northwest, they created greater demand for power. Congress concluded that additional multipurpose dams were essential for defense and industry, so it passed the Rivers and Harbors Act of 1945, which authorized McNary Dam on the Columbia and four multipurpose projects on the lower Snake: Ice Harbor, Lower Monumental, Little Goose and Lower Granite.

Today, Columbia Basin hydropower dams generate an average of 18,500 megawatts annually, serving eight million people. The Pacific Northwest derives two thirds of its electricity from hydro dams. Bonneville Power Administration coordinates this power system, controlling over 15,000 miles of transmission lines.

But power production was never the only purpose for building the dams.

Throughout the early 19th century the Columbia River provided a convenient means of transportation in a roadless land. Because the Northwest is an area physically isolated from centers of national trade and is crossed by rugged mountain ranges that made highway and railroad construction difficult and expensive, transportation was a key consideration on the Columbia and Snake rivers. By the middle of the 19th century larger vessels were traveling the river; the falls along the way were traversed by small rail lines along the banks.

In the early 20th century, water transportation advocates, dreaming of the completion of a 450-mile inland waterway to Lewiston, Idaho, pushed for further development of the river system. The campaign became more intense during the depression. Bonneville Dam was the first step in making Lewiston an inland port.

By the early 1990s, the Columbia River had become the fourth-most-valuable navigation corridor in the world. Annual shipping through Bonneville approaches 10 million tons. Ships carried almost five million tons of freight on the Snake River in 1995, about three million tons of which was wheat.

In the 1930s and 1940s, irrigation and flood control became prominent concerns. Irrigation projects transformed the Inland Empire, particularly eastern Washington, into one of the most fertile agricultural areas in the nation. Columbia River system dams provide irrigation water for almost 3 million acres.

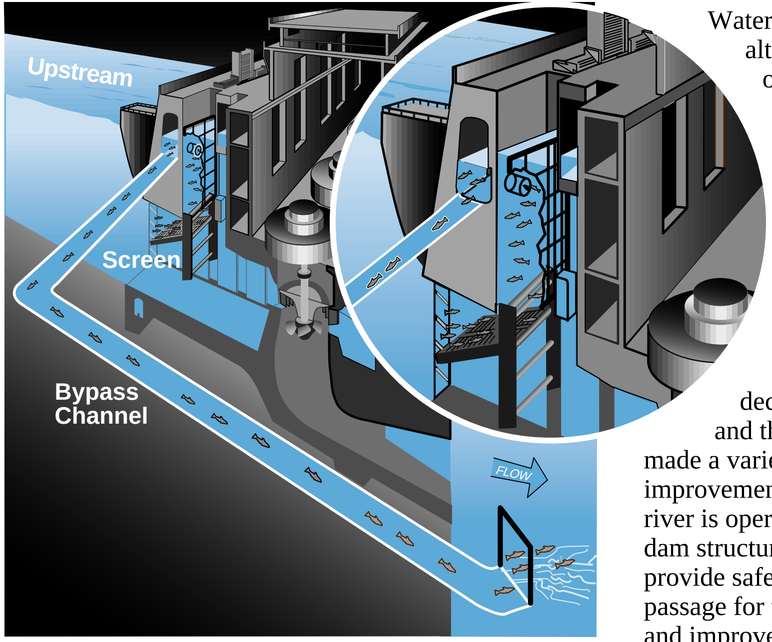
The Flood Control Act of 1936 added nationwide flood control as a federal responsibility. The devastating flood of 1948 in the Northwest further mobilized Congress to demand flood control in the area. In 1950 the Rivers and Harbors Act authorized construction of The Dalles and John Day Dams.

The dams also provide recreation and fish and wildlife benefits. Recreational boating, swimming and windsurfing are favorite uses in the reservoirs. In addition, lands are set aside as wildlife habitat to mitigate disruptive effects of dams.

These benefits came at the price of the watershed's anadromous fish runs. Since the 1930s, the Corps has coordinated and tried to balance the numerous, and often competing purposes in its management of the dams in the Columbia Basin. But the agency's most difficult problem—how to protect the anadromous fish runs—has yet to be fully solved.

The Dams and Salmon

When Grand Coulee Dam was built in eastern Washington in 1942 it had no fish ladders—so salmon were locked out from 1,100 linear miles of the Columbia River above the dam. The dams built by the Corps of Engineers on the Columbia and Snake rivers have systems designed to pass migrating fish. Still, fish migrating to and from the Snake River tributaries must pass through or over eight dams.



Juvenile Bypass System

When Bonneville Dam was approved in 1933, it was the first time engineers and scientists had ever tried to get migrating adult salmon over a 65-foot high dam. There had never been built in America or Europe a structure of such size that obstructed migratory fish runs of such magnitude.

At that time, the Corps formed a team of fisheries experts to draft a plan for passing adult fish upstream and young fish downstream. The team's task was formidable, and the experts could not agree on the best type of fishway. Eventually, an elaborate system of three reinforced concrete fish ladders, plus backup facilities consisting of traps, locks, elevators, and bypass canals, was devised. Its price totaled $7 million, approximately 15 percent of the original cost of the dam.

In June, 1938, after Bonneville Dam was put into full operation, engineers, biologists, and the entire fishing industry waited anxiously for the spring run of adult fish to appear. Adult salmon readily found and swam up Bonneville's fish ladders. This fish passage device was a success.

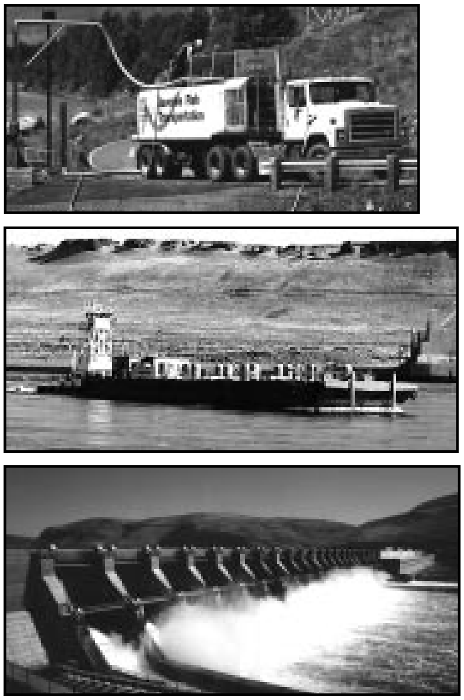
Inundation of spawning grounds is one of the most serious dam-related causes of fish mortality, often completely destroying spawning habitat. But dams cause a variety of difficulties for juvenile fish on their downstream migration to the sea. They alter the normal pattern of seasonal flow, with floods occurring later than normal or not at all. Water temperatures are altered. High levels of spill at dams elevate gas supersaturation levels which can be harmful to the fish. Reservoirs encourage the proliferation of predators.

Over the decades, the Corps and the region have made a variety of improvements in the way the river is operated and in the dam structures themselves, to provide safer migratory passage for the juvenile fish and improve survival rates.

Currently, there are four ways juvenile fish can navigate the dams: through the turbines; through the juvenile bypass systems; in specially equipped barges and trucks; or over the spillways.

Recent tests have indicated survival rates of 90 to 95 percent for juvenile fish passing through the turbines at some dams. Fish can be killed by pressure problems or blade strike. Others exit the turbines in a disoriented state and suffer increased predation in the tailrace below the dam.

From its beginning in 1951, the Corps' fish passage evaluation program looked at ways to divert young migrants away from turbine intakes. One result is the juvenile bypass systems currently in place at most of the dams. These take advantage of the juvenile fish attraction to the currents created by turbine operation. Huge submerged screens positioned in front of the turbines divert juveniles up into a gatewell, where they pass through orifices into channels that run the length of the dam. The fish are then either routed back out to the river below the dam or to a holding area for loading on transport barges or trucks. The survival rate for fish that go through the bypasses is around 98 percent. Juvenile bypass facilities are in place at seven of the eight lower Columbia and Snake River dams and planned for the eighth, The Dalles.



Truck and barge transport and spill for fish.

The guidance efficiency of the bypass systems is not perfect—about 70 percent of one species of salmon, fall chinook, swim under the submerged screens. On the other hand, the systems guide 80 to 90 percent of steelhead and 60 to 70 percent of spring/summer chinook salmon upward through the bypass channel.

The juvenile fish bypass system was later combined with a transportation system, where fish are barged or trucked from collector dams to downstream locations. The usual release destination is off the Skamania Light House—seven to eight miles downstream from Bonneville Dam and about 150 miles from the ocean. Transporting fish removes them from turbine passage, from nitrogen-saturated water, from predators—and they make the trip past the dams in a few days.

The Corps uses barges when the runs are highest, and trucks early and late in the runs when there are fewer fish. There are barges with capacities of 26,000, 50,000, or 75,000 pounds of smolts. River water circulates through the barges, allowing the young fish to imprint during the trip downriver. The barges also have a closed-circuit recirculation system which can shut off river intake completely if they encounter a contaminated section of river. Pumping systems maintain proper oxygen saturation and de-gas the water inflow to eliminate the potential for gas bubble disease in transported fish. The trucks can haul 1,750 pounds of smolts. Each trailer is equipped with a recirculation and aeration system.

Fish are collected at Lower Granite, Little Goose, Lower Monumental, and McNary dams for transport. In 1995 a total of over 18 million salmon and steelhead were transported.

Another way to get fish away from turbines is by opening dam spill gates so water and fish pass through the spillways rather than through the turbines. Spilling is considered a safe way to get fish past the dams—about 98 percent survive. It is efficient at diverting fish from the powerhouse area, the assumption being that if 50 percent of the water is spilled at a dam 50 percent of the juvenile fish in the river at that point are spilled.

But spill can create problems with gas supersaturation. As water plunges down a dam spillway, it entrains air. When this happens in a waterfall, the gas quickly returns to the atmosphere, just as dissolved nitrogen in a fast-moving river is rapidly freed. Dams create slack-water, low-velocity pools that do not purge dissolved nitrogen picked up from entrained air. When the gas concentration gets too high, it can give the fish “gas bubble trauma” where air bubbles form in the fishes’ circulatory system.

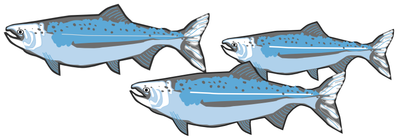
Spillway deflectors, or “flip lips” have been installed at five of the eight lower Columbia and Snake dams, to produce a more horizontal spill flow and limit the plunge depth of water over the dam spillway. This has helped reduce the amount of entrained nitrogen.

Seasonal releases of water from upstream dams can also aid salmon migration. Salmon evolved under spring flooding conditions which helped carry young fish to the sea. Storage dams hold back water, for flood control and other uses, interrupting the seasonal peaks. Some studies indicate that travel time of juvenile salmon decreases significantly in the Snake River as water flows increase, and that survival increases as flows increase. Until recently, water levels in the river have been determined not by needs of the fish, but by demand for power, irrigation, water and flood control.

In the early 1980s, the Northwest Power Planning Council, in consultation with the region, established the concept of a water budget. It called for specific amounts of water to be released from upstream storage dams to augment river flows for fish. The water budget has evolved into the current flow augmentation program whereby river managers attempt to bring flows up to levels that are believed to be beneficial for fish migration.

Salmon Endangered

Despite these and other efforts, three Snake River salmon species were listed under the Endangered Species Act. This triggered the requirement that federal agencies consult with the listing agency, in this case, National Marine Fisheries Service, on operations that might affect listed species.



Under the Endangered Species Act, the agency that lists a species issues a biological opinion following consultations with federal agencies whose actions could adversely affect the species. If the Biological Opinion finds that proposed agency actions would jeopardize the continued existence of the listed species, recommended measures to avoid jeopardy—the reasonable and prudent alternatives—are set out in the opinion.

On March 2, 1995, NMFS issued a biological opinion for operation of the federal Columbia and Snake River dams for 1995 and future years. It included reasonable and prudent alternatives to those proposed by the Corps for operating the system. The Corps then committed to implement these measures to the extent possible.

The Biological Opinion calls upon the Corps to implement numerous operational and structural measures at the eight lower Columbia and Snake river projects, and to simultaneously develop and evaluate new technologies, for improved fish passage at the dams.

In the 1995 fish migration season and again this year, flows in the system have been augmented, water and fish have been spilled at the dams, reservoirs were operated at lowered levels, and transport of juvenile fish by barge and truck has continued in accordance with the Opinion.

Structural improvements are being made at the dams in accordance with the Biological Opinion. A new juvenile bypass system was completed at the Ice Harbor Dam this year. Longer, more effective fish guidance screens have been installed in several existing bypass systems to increase the percentage of fish guided away from the turbine intakes. We will begin to install flow deflectors at Ice Harbor and John Day dams next year to help control gas supersaturation from spill.

As the operational and structural measures have been implemented, the Corps has at the same time aggressively explored new technologies for improved dam passage for fish. The Biological Opinion establishes a very ambitious schedule for development and testing of surface bypass systems, system-wide gas abatement techniques, reservoir drawdown options, fish bypass improvements, and other innovations such as fish-friendly turbines. NMFS is looking to a 1999 decision point for major decisions on Snake River drawdown versus the use of surface bypasses or other means for improved fish passage over the long term.

In spite of all the efforts devoted to fish protection, the numbers of returning adult salmon have taken a drastic downturn in recent years. That trend continued in 1995, with only 10,194 adult spring chinook and 15,030 summer chinook salmon passing Bonneville Dam by the end of July. The 10-year averages are 84,000 and 24,000 respectively. The adult spring chinook count in 1995 was 50 percent of what it was 1994, while the 1995 summer chinook count was 84 percent of what it was in 1994.

Some scientists are convinced that increasing flows, or drawing reservoirs down, and allowing the juveniles to migrate without transportation is the best solution. Others believe that the transportation system has been successful and that the successive drought years were the main cause of recent stock declines. Some believe that too many poor-quality smolts have been released from upriver hatcheries and these releases harmed, rather than helped, the recovery of fish runs. Poor harvest management and increased predation in reservoirs also have hindered the recovery of runs.

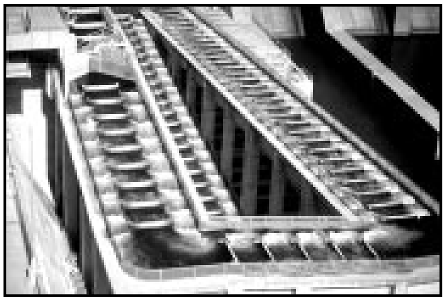
A recent report by the National Research Council, the research arm of the National Academy of Sciences, notes that "the salmon problem took many years to develop, and its solution will require the commitment of considerable time, money and effort" and that "solutions will be complex and often hard to agree on." The report cautions that the region must not focus on just one aspect of salmon recovery such as the hydro system, but must address all aspects of the salmon life cycle. For its part, the Corps is committed to making the river a better place for fish, working with the region to find scientifically sound solutions.

New Technologies

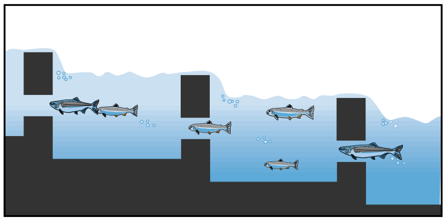
One new concept for a better way to get juvenile salmon past the dams is called surface bypass. This concept is simple in nature but could lead to improved survival of juvenile salmon as they approach and pass the dams. Basically, the surface bypass acts as a skimmer on the face of the powerhouse, or potentially at the spillways. Juvenile fish attracted to the powerhouse by turbine flows can pass through open slots in the surface bypass instead of diving toward the turbine intakes. There is evidence that the fish will move more quickly and with less trauma into the surface bypass than if they must dive down some 50-70 feet to the turbine area.

Another concept is drawdown of the reservoirs behind the dams to a level much lower than normal, even as far as natural river level. The idea is to reduce the cross section of the reservoir, thereby increasing the velocity of the river. In theory, this would speed the progress of migrating juvenile salmon. The Corps is studying the potential for drawdown of the four lower Snake River reservoirs—Lower Granite, Little Goose, Lower Monumental and Ice Harbor—to natural river level. There is also an interest in the region to study drawdown of John Day reservoir.

Other studies in progress focus on improved gas abatement during spill, refined turbine design to reduce turbulence and negative pressures, and use of light and sound, as well as physical barriers, to guide fish.



Adult fish ladder and cut-away view.



The Corps' Water Management office provides information on Technical Management Team activities and related information on the Internet at http://www.npd-wc.usace.army.mil/TMT/welcome.html.