BPA

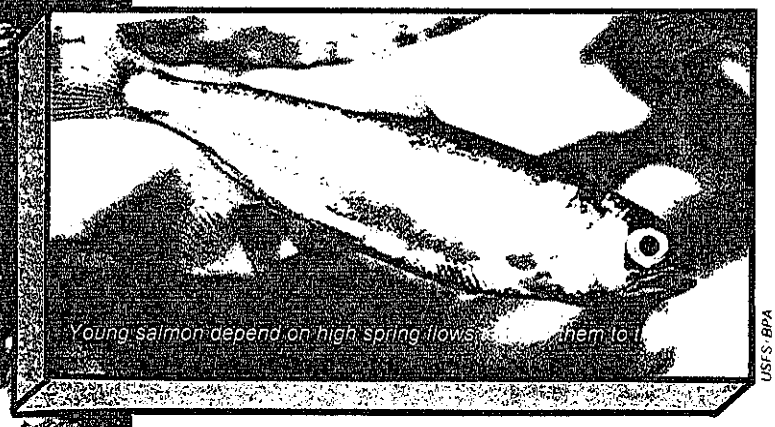
Issue Backgrounder: Downstream Fish Migration: Improving the Odds of Survival

Bonneville Power Administration
U.S. Department of Energy

April, 1987

Every spring, tens of millions of young salmon and steelhead leave spawning grounds and hatcheries on the Columbia and Snake rivers to start their long migration to the Pacific Ocean. These young fish, or **smolts,** depend on river currents to carry them downstream in four to five weeks. Timing is biologically critical: a delay can mean the smolts will die.

For millenia, the runoff from snowmelt unfailingly swept them to the ocean. But in more recent times that runoff has been held back-behind upriver storage dams used to generate electricity. Dry years have been particularly hard on the salmon population. Sometimes less than 10 percent have reached the ocean.



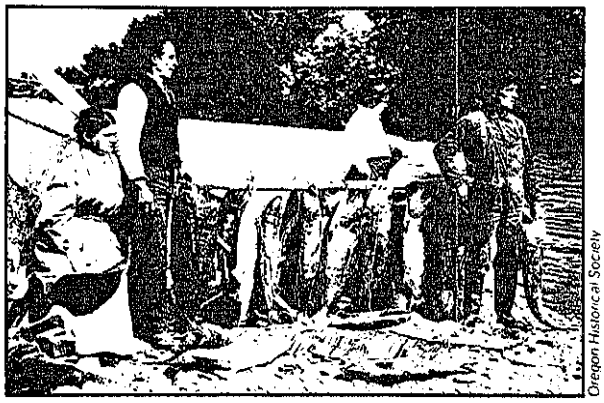
Young salmon depend on high spring flows [illegible] them to t

USFS-BPA

But times are changing: 1984 marked the first year of operation of the Water Budget, an allocation of water specially reserved for the spring migration. Now, if river currents are not strong enough, more than two billion gallons per hour of extra water can be released from reservoirs to carry smofts to the ocean.

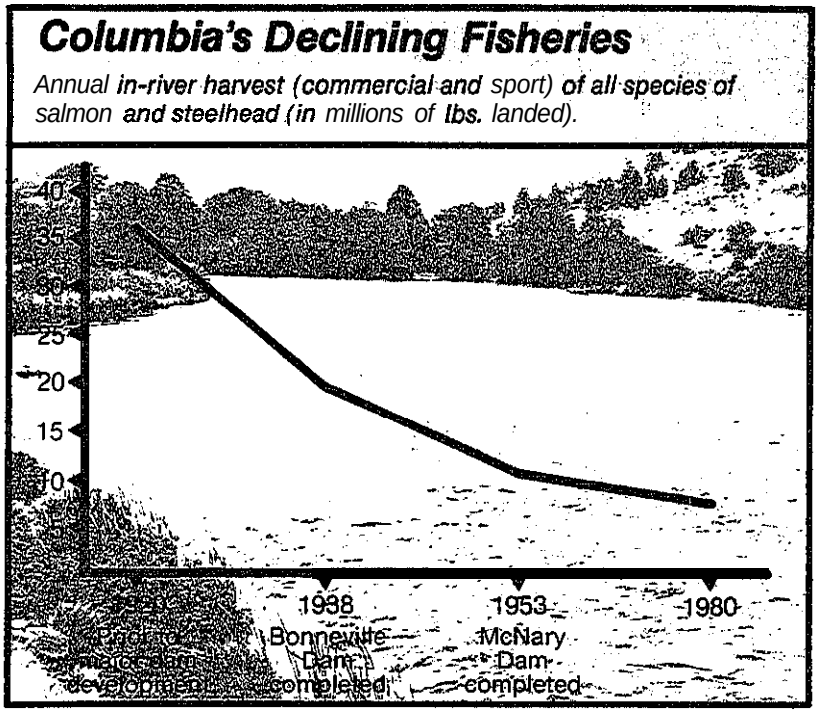
This is just one aspect of a long-term program run by the Bonneville Power Administration (BPA) and other agencies to reverse the serious decline of fish runs in the Columbia River system. Fish (and wildlife) now have a unique legal status that guarantees them "equitable treatment" with power generation and other programs in the management and operation of the Northwest's multipurpose Federal dams.

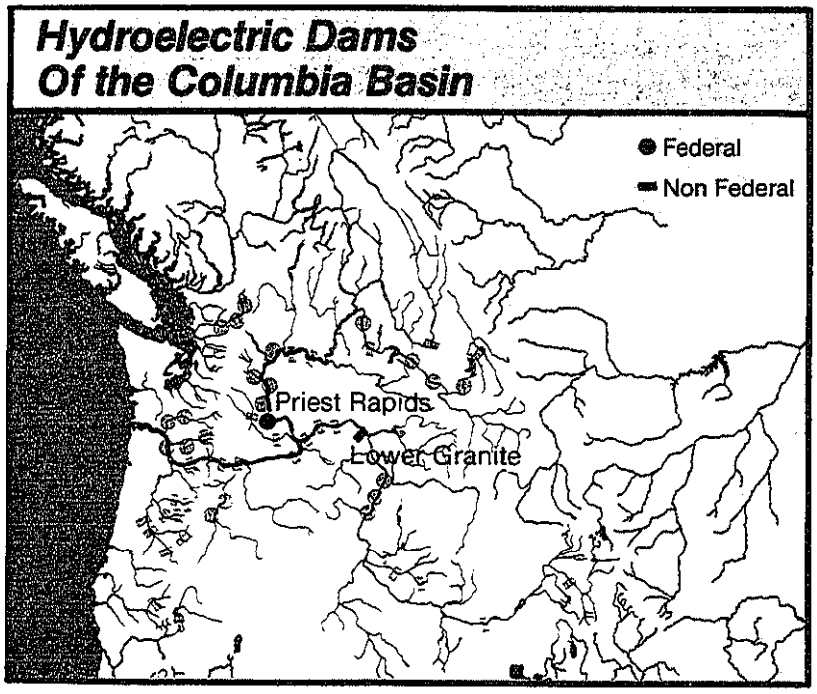
Jean



Oregon Historical Society

Fish catch on the Rogue River, Josephine County near Grants Pass, circa 1900.





The Water Budget monitors river flow at Lower Granite Dam on the Snake River and Priest Rapids Dam on the Mid-Columbia.

A Valuable Resource at the Brink

At the turn of the century, millions of fish returned from the sea each year to fight the currents to their native spawning grounds. But the seemingly limitless resource has dwindled drastically. The days when salmon and steelhead surged unhindered up the Columbia River and its tributaries have long since been consigned to history books, and live on only in local Indian legends and fishermen's tales.

The die was cast long before the first Federal hydroelectric project on the mainstem Columbia-Bonneville Dam-was completed in 1938. Under the Reclamation Act of 1902, Federal dams built for flood control and irrigation had already slowed natural river flows and blocked access to upriver spawning areas. Meanwhile, new canning techniques were streamlining the commercial salmon industry and creating a demand for ever-larger catches. While stocks were being overharvested, irreplaceable spawning habitats were being destroyed by a variety of other human activities.

Waterfront towns and settlements were built on the gravel beds where salmon and steelhead had laid their eggs for thousands of years. Cattle waded in the shallows and grazed on streamside vegetation. Farmers siphoned off water for irrigation and returned it to the rivers full of alkali and chemicals. Clearcutting caused soil erosion to silt up the streams, and logs jammed the narrows as they were rafted downriver.

The hydroelectric program that started in the 1930s could only hasten the decline of the fish runs. By the late 197Os, the 30 dams of the Federal Columbia River Power System were in place. The commercial salmon and steelhead harvest, now heavily regulated, was barely 15 percent of what it had been in 1920. Natural stocks of migrating fish were so depleted that Federal fisheries agencies even considered invoking the Endangered Species Act to protect certain upriver runs.

The Perils of Migration

Compared to the few natural obstacles that slowed juvenile salmonids' downstream migration only 150 years ago, the man-made barriers that now impede their journey seem almost impassable. A trip that once took 22 days can now take more than three times as long.

After a smolt leaves its native habitat far up the Columbia, River, it must traverse nine hydroelectric dams (five of them Federally owned) to reach the sea. From the farthest spawning grounds of the Snake River, it will face eight dams.

The first major problem the smolt encounters is the slow-moving current through dam reservoirs. For centuries, the migrating fish's "biological clock" has been synchronized with nature's swift water flows from spring runoff. Reduced flows and slower water velocities caused by dam operations place considerable biological stress on the smolt.

Migration time is closely linked to survival in a variety of ways. Substantial delays can cause smolts to die, or to lose their migratory urge and revert to a nonanadromous life cycle (see sidebar, "A Life Cycle That Ends Where It Begins"). Because their natural ability to adapt to saltwater only lasts about 30 days, prolonged delays may mean they cannot make the biological transition at the end of their journey.

In addition, the slow-moving, clear waters of the reservoirs tend to favor the predator-an advantage for many of the smolts' natural enemies, such as the squawfish.

If slow currents prolong migration into late spring or early summer, smolts are subjected to warmer water conditions-and significant environmental changes. Water temperature largely determines the composition of algae and plankton, as well as populations of other native fish and invertebrates. Higher temperatures can also reduce the migrant's resistance to disease, while increasing the prevalence of deadly viruses and bacteria.

The Dams: Hazardous to a Fish's Health

Once through the reservoir, the smOlt must somehow negotiate the physical barrier of the dam. Left to its own devices, the fish will either pass over the spillway (if water is spilling) or be drawn by the flow through the turbine.

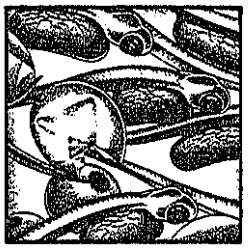
By far the most hazardous course is through the powerhouse turbine. As the smOlt moves from the top of the dam, down through the turbine intake and out a tunnel on the other side, it is subjected to extreme turbulence that can easily cause injury or death. Rapidly spinning turbine blades create a vacuum

A Life Cycle That Ends where It Begins

Chinook, coho, and sockeye salmon, and steelhead trout are all anadromous *salmonids* (from the Greek words ana-*dromos,* for upriver). The two major events of their life cycle are the hazardous downriver migration to the sea and, years later, the exhausting upriver journey to spawn where their life began. After they have laid and fertilized their eggs, all salmon die-though a few steelhead survive to repeat the cycle.

In the natural order, the fertilized eggs lie in shallow gravel nests, or *redds,* for about 50 days. However, a Columbia River salmon or steelhead these days is almost as likely to have started life in a hatchery.

a.



b.

The eggs hatch into *alevins*-embryonic fish that feed on nutrients stored in their yolk sac:They quickly grow into *fry,* learning to find food *among* the organic matter that drifts downstream. Within a few months they are *fingerlings* several inches long, seeking protected areas to build strength for the migration ahead.

Up to 18 months can pass before the young fish are ready for the downstream journey, which typically begins in spring on the fast current fed by melting snow. It is during this period that fingerlings undergo the process of *smoltificafion,* a physiological transformation that enables them to adapt to saltwater.

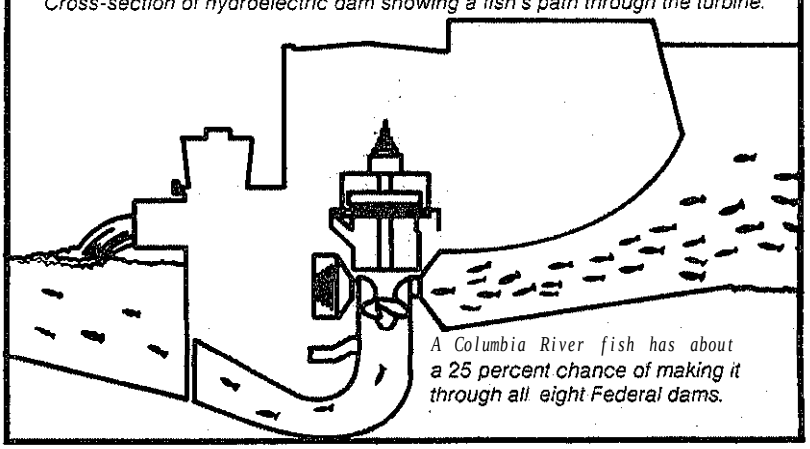
M Carpenter

c.

The smolts. as they are called, are now biologically programmed to head for the ocean. Of the millions that embark on the outward migration every year, only *a* few thousand ever make it back to ensure that the species survives for another cycle.

a. Salmon embryo a, 24 days, **b.** *Alevins — young salmon still attached to thei yolk* sac. **c.** Fingerlings — a few days before *migration.*

Cross-section of hydroelectric dam showing a fish's path through the turbine.

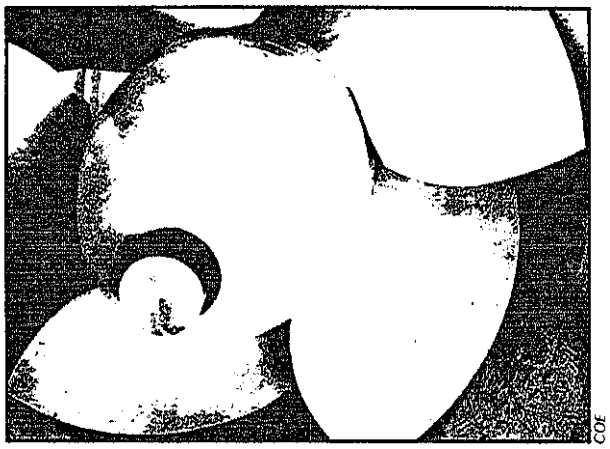


A Columbia River fish has about a 25 percent chance of making it through all eight Federal dams.

within the turbine housing that is often fatal to passing fish.

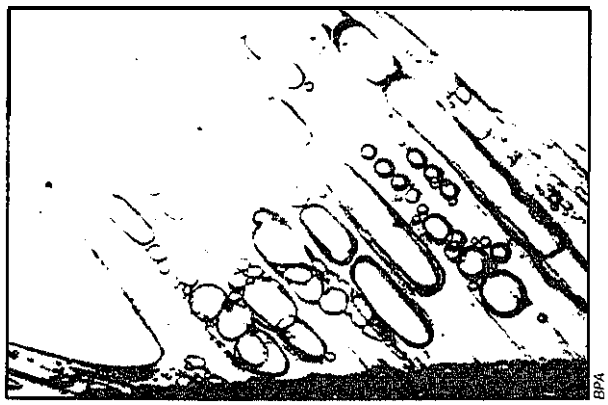
If the young fish survives, it often emerges injured or stunned at the base of the dam, or "tailwater." There, preying fish and birds congregate to pick off the disoriented stragglers. A smolt swept over the dam spillways also faces the same hungry predators when it splashes down after a sometimes lengthy fall, though it is less prone to severe injury There is yet another danger lurking in the tailwater: gas bubble disease. This potentially fatal condition is caused by the supersaturation of dissolved atmospheric gases, mainly nitrogen, in the turbulent water. This is similar to the "bends" sometimes experienced by human divers.

Some have estimated that juvenile fish mortality due to all causes can range from 15 to 30 percent per dam on the Columbia and Snake rivers. Smolts starting their seaward migration from one of the farthest spawning grounds suffer this loss at eight or more hydroelectric projects. Other estimates place the odds of making it to the ocean unaided at about one in four.



COE

Bonneville Dam turbine blades.



BPA

When fish are exposed to nitrogen supersaturated water, gas bubbles surface in the fins, displace internal organs and cause the eyes to pop out.

The Regional Act: *A Historic Step*

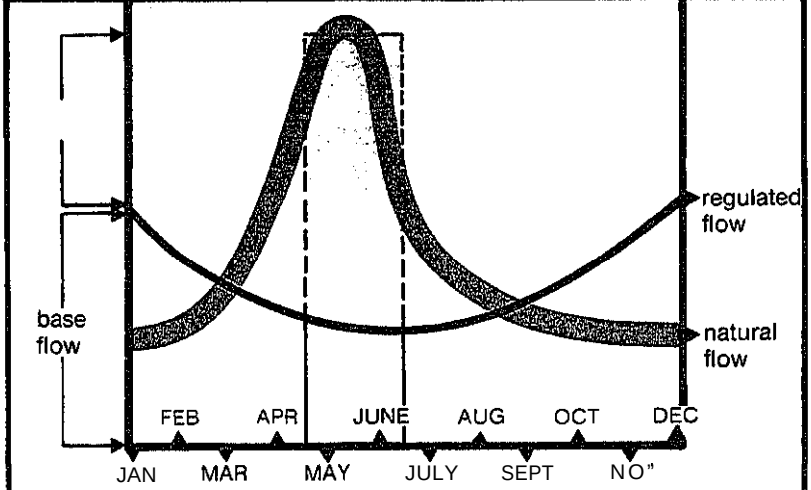
The rising chorus of concern from Indian tribes, commercial and sport fishermen, legislators, environmentalists, and state and Federal fisheries agencies finally found expression in the Pacific Northwest Electric Power Planning and Conservation Act of 1980.

This historic piece of Federal legislation redefined BPA's role in charting the region's energy future. Among other provisions, the Act assigned BPA an important new mission-the task of rebuilding the fish and wildlife populations in and around the streams and rivers of the Federal hydroelectric system.

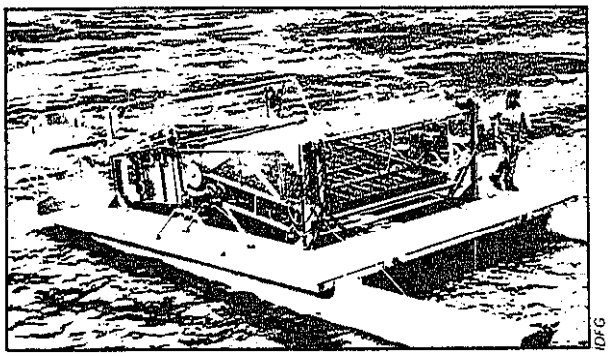
The Act gives BPA the authority to use its legal and financial resources "to protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries . . . ." While carrying out this new task, BPA must continue to ensure that the region has "an adequate, efficient, economical, and reliable power supply"

The Act also directed the Northwest Power Planning Council to develop and adopt a program to guide BPA and certain other Federal agencies in their efforts to protect fish and wildlife. By late 1982, after thousands of pages of testimony and hundreds of hours of public hearings, the Council's Columbia River Basin Fish and Wildlife Program was a reality,

Water Budget



How regulated flows are shaped to mimic natural flows and aid fish migration.

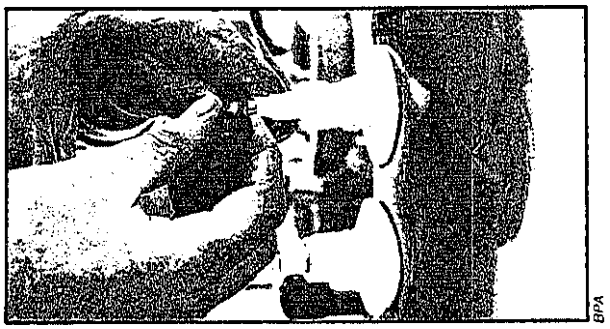

IDFG

A floating trap near Whitebird Creek, Salmon River, scoops up 1,200 smolts a day. Biologists count and identify the fish to determine travel time.

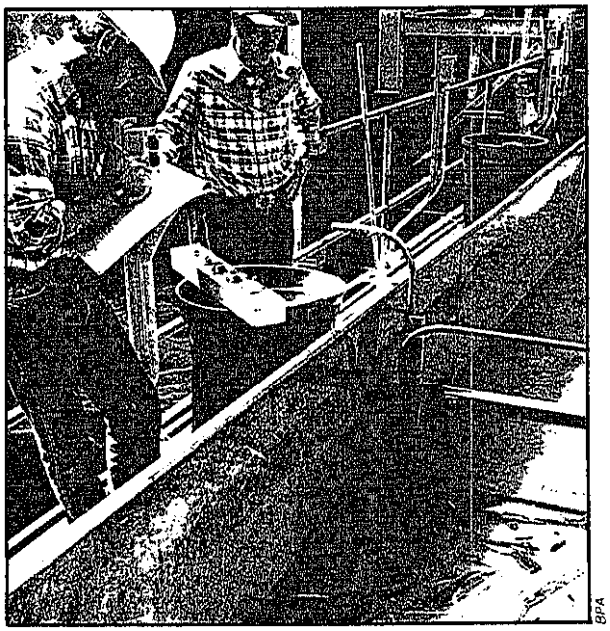
Crews from State and Federal fisheries agencies and several public utility districts also cooperate in other tagging and monitoring projects to measure the smolts' travel time and check on their health.

Crew members use liquid nitrogen to freeze-brand a special mark in one of several positions on batches of hatchery fish before releasing them. Biologists watch for the arrival of marked smolts at downstream monitoring sites and can then estimate travel time.

The water budget managers coordinate all smolt monitoring efforts and use the data collected to make decisions about whether and when to augment flows.


BPA

A fisheries worker freezes a special brand on a young salmon at Wells Dam Hatchery near Wenatchee, Washington.

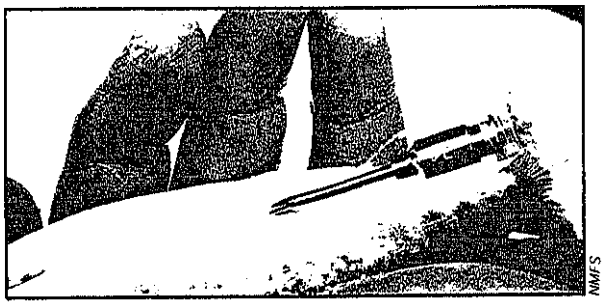

BPA

Barry Keesee, Chelan Co. PUD, and Larry Basham, WBC, count fish and check brands at eastern Washington's Rock Island Dam.

Computerized Tagging Simplifies Data Collection

A new fish-tagging system promises to revolutionize the collection of data on migrating salmon and steelhead. A miniature computer chip-called a passive integrated transponder, or PIT tag-is being developed for harmless implantation in the body cavity of young smolts.

The PIT tag, about the size of a grain of rice, stores one of 34 billion different codes. Each tag will provide researchers with a complete life history of the fish. The tag also incorporates a tiny antenna, enabling scientists to "read" its coded information with a decoder or data scanner from a distance of about one foot. Fish implanted with the tag at hatcheries can be monitored easily and repeatedly when they migrate downstream, and when they return later to spawn.


NMFS

A computer-chip "tag" in a young salmon's belly will permit fish managers to locate fish as they move downstream.

The conventional tagging system involves implanting a specially marked wire in a fish's snout. To retrieve the information, biologists must catch and kill the fish. Only five percent of tagged fish in the river can be monitored in this way. PIT tags will allow one person to retrieve information from some 99 percent of the tagged fish without harming or even handling them.

Computerized tags are expected to become commonplace in the Northwest's hatcheries, making a very high level of data available to Water Budget managers for accurate planning of flows.

Moving Smolts Past the Dams

Moving smolts more rapidly through the dam reservoirs certainly increases their chances of survival, but they need help at the dams, too. Biologists estimate that the turbines alone account for between 11 and 15 percent of fish mortality.

Various techniques have been tried over the past 50 years to bypass fish around power-

The Water Budget: Shaping Flows to Aid Migration

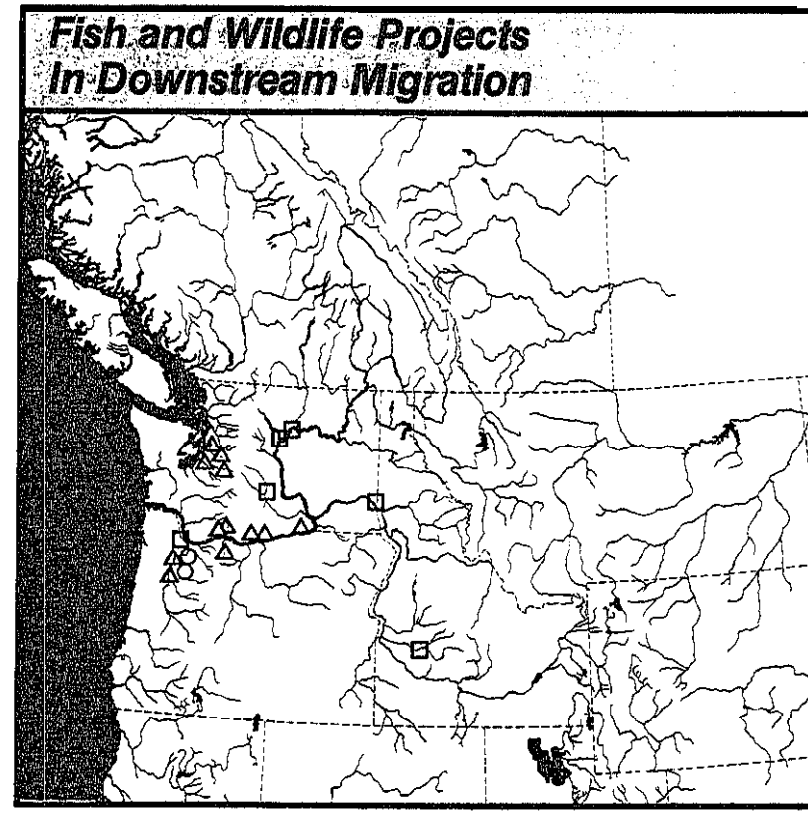
In 1966 BPA spent $25 million on more than 100 projects addressing the problems salmon and steelhead face from hydroelectric generation. Currently, 14 of those projects are aimed at helping young fish survive the man-made obstacle course they must run to reach the ocean.

One of the most innovative arrangements, and the cornerstone of the whole program to rebuild diminished fish runs, is the water budget. In this program, two Water Budget managers-one representing regional fisheries agencies and the other representing Columbia River Indian tribes-cooperate with power-production managers from various Federal agencies to "shape" river flows around fish movements.

From April 15 to June 15 each year, when the downstream spring migration reaches its peak, a predetermined amount of water can be released from upriver storage dams to help "flush" smolts downstream. This is more than a token gesture. It has been estimated that if the total water budget were reserved for power generation instead, it could be worth between $40 million and $100 million a year in BPA revenues,

This extra release of water is times to parallel the spring runoff that would carry juvenile fish to the sea under natural conditions. Water Budget releases can be scheduled to get the largest number of smolts through slack-water reservoirs in the shortest possible time, reducing their exposure to disease, predation and stress. Faster flows also help smolts get to the ocean while their migratory urge and ability to adapt to saltwater are intact.

How does the water budget actually work? In practice, water flow on the Columbia and Snake rivers is supervised for fisheries purposes at two monitoring points: at the Lower Granite Dam on the Snake River and at Priest Rapids Dam on the Mid-Columbia. The water budget managers monitor the flow rates at these points. At their disposal is an amount of water equivalent to a month-long flow of 20,000 cubic feet per second (cfs) at Lower Granite Dam, and a month-long flow increase of 56.000 cfs at Priest Rapids. Whenever these managers find it necessary for migrating fish, they may request that the Corps of



Engineers release a certain part of this annual water budget.

During 1964, the first full year of operation, above-average natural streamflow eliminated the need for supplemental water releases from the Water Budget on the Snake River. However, the total 56,000 cfs allocation was used on the Mid-Columbia.

Smolt Monitoring Program Tracks Downstream Progress

To use the Water Budget most effectively, the managers depend on regular information on the movements and general condition of sea-bound smolts. Several monitoring studies are underway throughout the Columbia River hydro system.

In a BPA-funded study at Lower Granite Reservoir, researchers catch fish in special traps and inspect them for descaling and other evidence of deteriorating health. They also document the arrival of large groups of smolts-important information for water budget managers, who schedule water releases to coincide with fish movements.

Another study provides estimates of the number and estimated time of arrival of summer migrants at Priest Rapids Dam.

DOE/BP-441
Second Printing, Revised
April 1987
5M

fish-squawfish, walleye, and smallmouth bass-which may inflict considerable losses on disoriented smolts. Use of pesticides is even being considered to control squawfish, the most voracious of the predators. Special chemicals, such as squoxin, can be used selectively to kill squawfish without harming other fish.

In a joint program run by BPA and the Corps of Engineers, biologists monitor the levels of dissolved gases in dam tailwaters and check the fish regularly for symptoms of gas bubble disease. In addition, the supersaturated water can be partly controlled by installing spill deflectors and by regulating spill.

Opening day Oregon's sport fishing season

A Promising Start

Before the impact of these programs to aid downstream migration can be fully assessed, returns of adult fish will have to be monitored for several years. Meanwhile, biologists hope the programs will provide adequate solutions to the most significant threats to anadromous fish on the Columbia and Snake rivers.

While hydroelectric projects clearly contribute to high mortality among smolts, it is difficult to determine exactly to what extent they are responsible for diminished runs. Many other factors influence smolt survival rates and the number of mature salmonids that return to spawn after two to four years at sea. Legal and illegal harvesting, pollution, habitat degradation from causes other than power generation, and depletion of salmonids' food stocks all play a part.

Then there are other unexplained factors at play. The abundant steelhead trout and fall chinook runs in 1984, for example, were the best in 25 years. Sockeye salmon, which had not been commercially harvested for 20 years, also made a dramatic reappearance in 1983. The reasons still remain a mystery.

BPA is fully committed to improving conditions for fish and wildlife so they may survive and thrive in a drastically changed environment. The fact that this effort now carries the full weight of law opens a new chapter in the region's history.

BPA is fully committed to improving conditions for fish and wildlife so they may survive and thrive in a drastically changed environment. The fact that this effort now carries the full weight of law opens a new chapter in the region's history.

For Further Information

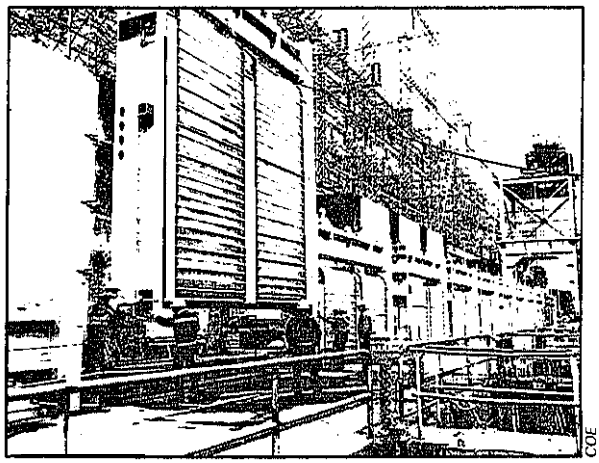
If you would like more information on the programs described here, contact your nearest BPA Area or District office, the BPA Division of Fish and Wildlife, or the BPA Public Involvement Office, Division of Fish and Wildlife, P.O. Box 3621, Portland, OR 97208: 503-230-4981. Public Involvement Office, P.O. Box 12999, Portland, Oregon 97212; 503-230-3478 (teletypewriter service available for the speech and hearing impaired). Or call toll-free in Oregon, 800-452-8429; and in other Western states, 800-547-6048.

BPA Area and District Offices

Portland	503-230-3490
Eugene	503-687-6952
Seattle	206-442-4130
Spokane	509-456-2515
Missoula	406-329-3060
Wenatchee	509-662-4377
Walla Walla	509-522-6226
Idaho Falls	208-523-2706
Boise	208-334-9137

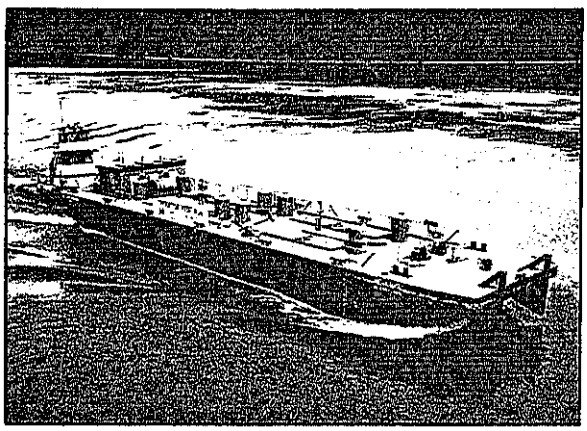
house turbines. But it was not until 1969 that ah effective mechanical device-called a submersible traveling screen, or STS-was developed. The screen is now used by the Army Corps of Engineers at about half of the Federal dams.

The STS diverts fish out of turbine intakes and guides them into "gatewells." From there, they enter a trash sluice or other conduit that carries them safely down to the tailwater or to a collection area. The STS bypass systems, which cost up to $30 million at each dam, currently prevent about half the smolts from passing through turbines. Biologists estimate the STS has the potential to intercept as many as 70 to 80 percent of all smolts.


COE

Engineers install a new fish screen into a Columbia River dam.

Another method of helping migrating fish past the dams is to physically transport them down the river by truck or barge. The STS bypass systems guide fish to holding facilities, where they are collected, tagged, and transferred to truck-drawn fish trailers or river barges. These smolts then get a comparatively safe ride to a point below Bonneville Dam, where they are released just a few days' swim from the ocean.



Biologists study the stresses on fish transported by barge around Lower Columbia River dams.

To be sure, transported fish may have special problems. of their own. The stress they experience in the holding tanks may be enough to eventually kill them. Some hatchery fish also may have difficulty retracing the route to their stream of origin. A number of studies are underway to confirm and find solutions to these problems. But all in all, survival rates have been found to be higher for transported fish (particularly steelhead) than for fish that make their own way downstream.


BPA

By pumping stomachs, biologists determine what predatory fish eat, how much they eat and what hours of the day they feed.

Several Federal dams have inadequate bypass facilities-among them John Day, Lower Monumental and The Dalles. Here the Corps of Engineers and BPA reserve a volume of water to provide "spill" specifically to help smolts over the dams. (This is quite separate from the water budget, which is only intended to get fish between dams.) In 1995. this effort cost BPA roughly $27 million.

However, this technique is considered a temporary measure, pending installation of permanent bypass facilities. Many non-Federal dam operators in the Columbia hydro system also use spill to cut down on turbine-related losses. And, of course, forced spill from full reservoirs serves the same purpose.

Smolts still have to face major hazards-preying birds and fish, and gas bubble disease-in the dam tailwater after their ride over the top. Several BPA studies are being conducted to determine the behavior patterns and feeding habits of the major predatory